TECHNICAL REPORT

Harbor Monitoring Program for San Diego Region San Diego Bay, Mission Bay, Oceanside Harbor, and Dana Point Harbor

Prepared for:

Port of San Diego
City of San Diego
City of Oceanside
County of Orange

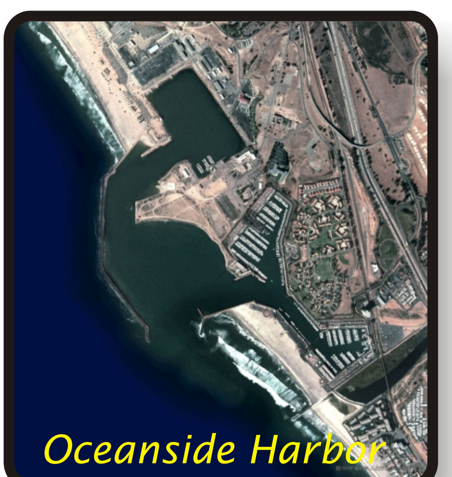
Prepared by:

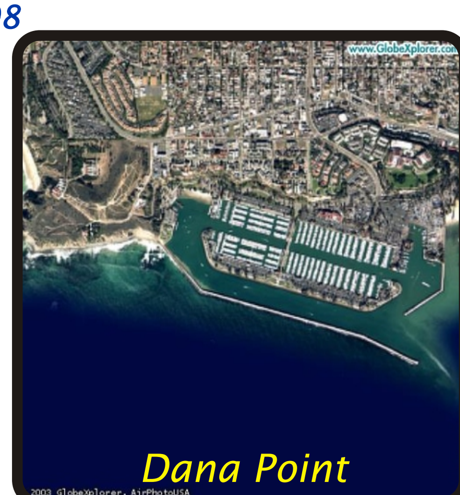
MFC ANALYTICAL SYSTEMS, INC.
2433 Impala Drive
Carlsbad, California 92008

and

Brock Bernstein

February 2004





TECHNICAL REPORT

Harbor Monitoring Program for San Diego Region San Diego Bay, Mission Bay, Oceanside Harbor, and Dana Point Harbor

Prepared for:

Port of San Diego
City of San Diego
City of Oceanside
County of Orange

Prepared by:

MEC ANALYTICAL SYSTEMS, INC.
2433 Impala Drive
Carlsbad, California 92008

and

Brock Bernstein

February 2004

TABLE OF CONTENTS

INTRODUCTION

The County of Orange, the City of Oceanside, the City of San Diego, and Port of San Diego have developed this proposal for a San Diego Regional Harbor Monitoring Program in response to the July 24, 2003 request by the San Diego Regional Water Quality Control Board (RWQCB) under §13225 of the California Water Code. The RWQCB has requested the submission of a technical report to consist of a coordinated and comprehensive harbor water quality monitoring program. The intent of this coordinated program design is to develop a proposed coordinated monitoring effort of harbors in the San Diego Region to provide water quality status and trends information, as well as, assess the surface water's abilities to support designated beneficial uses. This proposal was developed to obtain funding under the California Surface Water Ambient Monitoring Program (SWAMP).

This document provides a framework for the development of a San Diego Regional Harbor Monitoring Program (RHMP). The largest single component of the RHMP is the ambient monitoring program, because it provides the status and trends information on a broad scale for the San Diego Region Harbors. This document describes the RHMP ambient monitoring design strategy, the statistical basis of the monitoring design and the approach to the program. Further it identifies the questions that still require answers in order to satisfy the final program design. It proposes a plan of action which includes steps for a limited scale monitoring program (pilot program) to obtain the information necessary to satisfy the final program design.

In addition to the ambient monitoring program, special focused studies address specific questions related to beneficial uses. This document also describes existing monitoring programs that satisfy specific questions related to beneficial uses, and provides a specific study design for a proposed copper loading study in San Diego Region marinas.

SECTION 1 PROGRAM GOALS AND DESIGN APPROACH

The overall goal of the proposed RHMP is to assess water quality status and trends in the local harbors. The RHMP is focused on collecting information on baseline conditions and the effects of pollution sources. Monitoring will focus on the condition of beneficial uses. This program employs different types of monitoring efforts to address the various questions posed by the RWQCB. The program is designed to integrate with existing monitoring that is regularly conducted in the region, including storm water monitoring, other permit compliance monitoring, regional Bight monitoring, and special focused studies. This program is designed to both meet the requirements of RWQCB's letter and integrate with the State's SWAMP.

The County of Orange, the City of Oceanside, the City of San Diego, and Port of San Diego are also interested in establishing a closer link between state-mandated water quality program activities and the impact those activities have on protecting and improving water quality. The ability of both the RWQCB and the County of Orange, the City of Oceanside, the City of San Diego, and Port of San Diego to relate the performance of their programs directly to water quality outcomes has been hampered by limited coordinated data management and evaluation efforts.

The program goals outlined above are designed to address the purpose stated in the RWQCB's request. RWQCB July 24, 2003 §13225 Request:

> *The purpose of a coordinated regional monitoring program for San Diego Region harbors is to identify the water quality status and trends and the ability of surface waters to support beneficial uses over the long term.*

1.1 Monitoring Objectives

In developing the proposed RHMP monitoring objectives, the County of Orange, the City of Oceanside, the City of San Diego, and Port of San Diego used the State Water Resources Control Board's November 30, 2000 Report to the Legislature, entitled "Proposal for a Comprehensive Ambient Surface Water Quality Monitoring Program," as guidance for developing clear monitoring objectives. The objectives of the RHMP are based on and directed at the five major questions and seven issues presented in the RWQCB's July 24, 2003 request. The questions and issues are identified below.

Question 1 What are the contributions and spatial distributions of inputs of pollutants to harbors in the San Diego Region and how do these inputs vary over time?

Question 2 Are the waters in harbors safe for body contact activities?

Question 3 Are fish in harbors safe to eat?

Question 4 Do the waters and sediments in the harbors sustain healthy biota?

Question 5 What are the long-term trends in water quality for each harbor?

Issue A Identification of significant contributors of waste loading. Example: Loading from boat hulls due to passive copper leaching.

Issue B	Develop ambient sampling approach for water and sediment capable of identifying water quality status and trends.
Issue C	Develop focused monitoring approaches in designated portions of water bodies.
Issue D	Coordination and integration with Southern California Coastal Waters Research Project's Regional Bight Monitoring Program.
Issue E	Consider existing permit monitoring programs and ways to eliminate duplication.
Issue F	Electronic data storage and retrieval.
Issue G	Public availability of reports.

1.2 Design Approach and Philosophy

One of the most common mistakes made in monitoring programs is inadequate effort in the upfront design of the program to ensure that the program will yield information to answer the original technical questions with adequate statistical confidence or power. In too many instances, programs are implemented at great expense in monitoring, analyses, and data management without adequate upfront planning and limited, if any, statistical program design; yielding limited statistically valid information. Understanding the importance of statistical design models to the ultimate outcome of the monitoring program, the RHMP started with the upfront design process so that this program will ultimately be scientifically sustainable.

The first step in the development of the monitoring program design was to categorize the RWQCB letter questions and issues into monitoring types, identifying if they would be best answered through a core "ambient" monitoring program or if the question was more appropriately addressed through a focused "special" study. This step allows the categorization of the questions for study design. It is crucial to accurately categorize and refine the questions to ensure the design of the program will actually yield answers to the specific questions. This step is iterative in that it is revisited following the refinement of design questions to ensure that the questions are best answered either in core (long-term ambient) monitoring or focused studies.

Core monitoring is also referred to as ambient monitoring and describes a long-term monitoring program developed to answer questions related to status and long-term trends. Focused studies refer to shorter duration studies designed to answer specific questions that do not require long-term assessment. An example of a core monitoring question is, "What are the trends in concentration of total metals in harbor sediments? Are concentrations increasing or decreasing?" An example of a focused study question is, "What are the source(s) of zinc to harbor sediment?"

By categorizing the questions and issues contained in the RWQCB July 24, 2003 letter, the following items were deemed suitable to address through a core monitoring program design.

Question 1 What are the contributions and spatial distributions of inputs of pollutants to harbors in the San Diego Region and how do these inputs vary over time?

Question 2 Are the waters in harbors safe for body contact activities?

Question 3* Are fish in harbors safe to eat?

Question 4 Do the waters and sediments in the harbors sustain healthy biota?

Question 5 What are the long-term trends in water quality for each harbor?

Issue B Develop ambient sampling approach for water and sediment capable of identifying water quality status and trends.

Issue D Coordination and integration with Southern California Coastal Waters Research Project's Regional Bight Monitoring Program.

Issue E Consider existing permit monitoring programs and ways to eliminate duplication.

Issue F Electronic data storage and retrieval.

Issue G Public availability of reports.

*Question 3 will be addressed in the core monitoring program less frequently than the other questions. For example, fish tissue sampling and analysis will be conducted every 5-10 years as opposed to more frequently. (Bernstein et al. 1999)

Issues that are suitable for addressing through focused studies include the identification of significant contributors of waste loading. All monitoring programs shall be designed with consideration of existing programs so that resources are effectively leveraged (Issue E). Other issues, including data storage and public availability of data (Issues F and G) shall be a part of all RHMP monitoring, both core and focused studies. The following issues from the RWQCB letter are addressed through focused studies:

Issue A Identification of significant contributors of waste loading. Example: Loading from boat hulls due to passive copper leaching.

Issue C Develop focused monitoring approaches in designated portions of water bodies.

Issue E Consider existing permit monitoring programs and ways to eliminate duplication.

Issue F Electronic data storage and retrieval.

Issue G Public availability of reports.

SECTION 2 RHMP CORE MONITORING PROGRAM

The proposed RHMP core monitoring program is a comprehensive effort to survey the general water quality and condition of aquatic life in the harbors and to determine whether beneficial uses are being met. Core monitoring is the collection of information about the status of the physical, chemical, and biological indicators. This information can be used through time to compare trends in those indicators, as well as, status of those indicators. The monitoring typically provides trend information by being repeated at a specified frequency to obtain statistical trend data for the indicators.

2.1 RHMP Core Monitoring Design Goals

There are a variety of approaches that could be taken to develop a RHMP. In order to guide the study design specific refined goals were identified which directed the development of the statistical model. The refined goals of the Core monitoring program are to:

- develop technically valid answers to specific questions.
- be scientifically sustainable.
- be reasonably economical to implement.
- be similar enough to Bight Program approach to allow direct integration.

2.2 RHMP Core Monitoring Questions

To develop a strong statistically based RHMP design, it was important to refine the monitoring questions into statistically based questions. This process allows the identification of design characteristics to best answer each monitoring question. In order to answer RWQCB Question 1, as well as allow for integration as described in Issue B, it was determined that Core Monitoring would best be addressed through the identification of specific areas of harbors or “strata” that would be relatively homogeneous internally in terms of both monitoring questions and environmental features. The use of strata to define monitored areas is uniform with the Bight program. It also allows for a reasonable identification of harbor inputs (based upon land uses and activities within each harbor area) as well as comparison between areas. The five strata identified (preliminarily) for the core monitoring program are; marina areas, shallow water areas, deep water areas, freshwater input areas, and industrial/port activities. Not all harbors may have all five strata.

The questions being asked in core monitoring are further refined to the following:

Refined Question for Study Design	**Related RWQCB Question**
How much of the area of each stratum is above/below relevant benchmarks?	Q4- Do the waters and sediments in the harbors sustain healthy biota? Q2 - Are the waters in harbors safe for body contact activities?
How has the area of each stratum above/below benchmarks changed over time?	Q1- What are the contributions and spatial distributions of inputs of pollutants to harbors in the San Diego Region and how do these inputs vary over time? Q4 -What are the long-term trends in water quality for each harbor? Q5- What are the long-term trends in water quality for each harbor?
What is the average measure of relevant indicators in each stratum?	Q1-What are the contributions and spatial distributions of inputs of pollutants to harbors in the San Diego Region and how do these inputs vary over time? Q4-Do the waters and sediments in the harbors sustain healthy biota?
How has the average measure of relevant indicators in each stratum changed over time?	Q5- What are the long-term trends in water quality for each harbor?
How different are the average values of relevant indicators in different strata?	Q1- What are the contributions and spatial distributions of inputs of pollutants to harbors in the San Diego Region and how do these inputs vary over time?
How has the degree of difference between strata changed over time?	Q1-What are the contributions and spatial distributions of inputs of pollutants to harbors in the San Diego Region and how do these inputs vary over time? Q5- What are the long-term trends in water quality for each harbor?
Are the fish tissue concentrations above/below relevant benchmarks?*	Q3-Are the fish safe to eat?

*Question 3 – Are the fish safe to eat? Is not a question that involves comparison between strata as fish move throughout the harbor area and are not confined to a particular stratum. Question 3 is a comparison to a benchmark/threshold value. For question 3 the various strata can not be compared, however, fish from each harbor area could be compared between harbors.

2.3 RHMP Core Monitoring Statistical Model Design

To be successful, the core monitoring program needs to provide adequate information to allow statistically valid statements to be made about of the conditions in the waterbody and the trends (improving or degrading over time) in the water body. The study design must be carefully considered in order to select the design model that will provide the most efficient use of resources to cost effectively answer the study questions. The RWQCB letter stated that “a coordinated monitoring program should prioritize monitoring efforts and allocate resources.”

A review of the various potential approaches with both the goals and refined questions in mind resulted in the selection of a binomial model using a preset constant target percentage or proportion. In other words, a target percentage of area exceeding a threshold concentration level of each indicator of interest (e.g. chemical or fauna) would be established. These threshold levels would take the form of concentration levels for chemical constituents, abundance levels or a Benthic Response Index (BRI) for infauna, or toxicity level for bioassays. Thus, for example, monitoring would be designed to ensure an ability to determine whether more than X% of the area was above a specific BRI value. This will be done in two steps. The first is to establish a threshold level; the second is to use historical data to determine the percentage of area in harbors exceeding that threshold level to establish a baseline or baseline percentage.

The threshold levels for various indicators can be derived from the Basin Plan, the California Toxics Rule, or some other measure or index of impairment. Alternatively, the historical data from the harbors could be mined and the 80^{th} percentile (or other percentile) value could be selected as the threshold level. The percentile could be based on an inflection point in the cumulative distribution of the data if a clear empirical inflection point exists.

The preset target proportion or percentage then needs to be established. This proportion then becomes the constant in the binomial model (Cohen 1977). The proposed study design requires the establishment of the constant as current baseline for the harbors, defining the percentage or proportion of historical stations in the harbors that exceed the threshold level. This would be accomplished through data mining of the Southern California Bight Projects’ Bight ‘98 and (possibly)’03 information for the indicators within each stratum. This will determine the preset target proportion and allow for comparison in the first year of the program using the binomial approach. A more detailed discussion of the statistical design is presented in Appendix A.

One might reasonably ask: why go through all of these steps and undergo all of this effort? If the statistical program design is not carefully considered, either:

- the model design will not reflect the USEPA Environmental Monitoring and Assessment Program (EMAP) and Bight programs (Issue D),
- the ultimate monitoring effort will have to be 3 to 4 times greater (and more expensive) in order to achieve the same testing (decision making) power and confidence that are inherent in the EMAP and Bight programs, or
- the confidence bounds will be greatly expanded and the power reduced. For example, using the approach without pre-established thresholds and target proportions, if the measured percentage of area of a stratum above (or below) a threshold level of an indicator was 50% the 95% confidence bounds would range from 0.18 to 0.82 for a sample size of 32 samples per stratum.

Stations will be identified through a stratified random approach using hexagons to define areas represented by each station. This approach:

- Allows determination of what proportion (%) of an area exceeds a threshold or benchmark.

In addition, regression analyses:

- Allows determination of the area of each stratum above or below relevant benchmarks changes through time (as program moves forward temporally through trend assessment).

The approach combined with an Analysis of Variance (ANOVA) of the resultant data will allow:

- The determination of the average measure of relevant indicators in each stratum.
- Changes in the average measure of relevant indicators in each stratum to be tracked through time.
- A comparison of how average values of constituents differ between various strata.
- The degree of difference between strata to be tracked through time.

2.4 RHMP Core Monitoring Program Design Elements

The design of the monitoring program is critical to comparison with other programs and integration both with on-going routine monitoring and Bight monitoring. The design elements detailed here will require further development and confirmation through the pilot program.

2.4.1 Strata

The strata proposed for sampling are: freshwater inputs, shallow water, deep water, marinas, and port/industrial. Not all harbor areas will have each stratum.

2.4.2 Monitoring Indicators

The components for monitoring are: sediment (chemistry, benthic community, and toxicity), fish (tissue), and water quality (chemistry, toxicity, and general parameters). For monitoring indicator categories see Section 2.5.1.

2.4.3 Monitoring Timing and Frequency

The proposed RHMP core monitoring is to be conducted during the summer months. The summer months were selected for the monitoring period because there will be stabilization of the benthic community following winter storms and spring generation. Additionally, this timing allows for integration with the Bight program, as Bight monitoring is conducted in the summer months.

2.4.4 Methodology and Procedures

Sample collection, processing, and analysis shall follow the detailed methodology and procedures established by the Bight process to allow for data integration. Data will be stored electronically to meet RWQCB Issue F and allow integration with Bight and Municipal Urban Runoff Monitoring programs.

2.5 Information Needs

Prior to proceeding with the RHMP Core Monitoring Program, additional information is required to fulfill the design criteria. The following are information needs to satisfy the final design.

2.5.1 Identify the indicators

The identification of the indicators for the monitoring program together with appropriate measurement methodologies and minimum detection limits (for chemical indicators) must be completed. The indicator categories have been identified as microbiology, chemistry, benthic community, toxicity, and physical indicators. The refinement of the indicators of interest shall be developed through review of the existing monitoring programs to ensure appropriate integration of the data. Existing monitoring programs, including the Bight monitoring program will be reviewed for indicators, detection limits, and methodologies to establish the details of the monitoring program.

2.5.1 Establish the threshold levels

Thresholds for each indicator of interest (chemical, benthic community, toxicity) above which there is concern must be established. What criteria should be used for the threshold levels? There are a variety of options. For example with sediment chemistry is it appropriate to use Long et al. (1995) Effect Range Low (ER-L) and Effect Range Median (ER-M) sediment quality guidelines? Or a reference approach using Bay Protection Toxic Hotspot Program and the Bight '98 data? Or some other Sediment Quality Guideline benchmark (there are many). Each parameter will need to have benchmarks established/set and agreed upon prior to program implementation.

2.5.2 Establish the preset target proportion or percentage

This design requires establishment of these percentages by determining the current baseline for the harbors, specifically what proportion or percentage of historical stations in the harbors exceed the threshold levels for the indicators (Sections 2.5.1 and 2.5.2). This would be accomplished through data mining of Bight '98 and (perhaps) '03 data. Other available harbor data will also be used if appropriate (i.e., NPDES compliance monitoring programs, special studies). A sediment quality database is currently being developed by SCCWRP and this is one source of San Diego Region sediment data.

2.5.3 Complete detailed mapping to verify stratum areas

Detailed maps for identification and delineation of specific stratum within each harbor area must be accomplished to allow for both accurate review of historical data for the preset targets development (Section 2.5.3) and placement of hexagons for development of the Sampling and Analysis Plan.

SECTION 3 RHMP CORE MONITORING PILOT PROGRAM

The implementation of a collaborative regional approach to harbors will require an extensive commitment of resources. It is crucial that any regional program implemented is scientifically sustainable, provides technically valid answers to specific questions, is reasonably economical to implement, and allows for direct integration into other large scale monitoring programs (such as Bight Monitoring). To ensure that these objectives are met by the RHMP Core Monitoring Program, a pilot program is recommended as the appropriate approach to implement the monitoring and ensure that the design is appropriate prior to investment of resources and commitment to full scale implementation. The use of a pilot program allows the design to be verified—will it answer the refined questions? The pilot program provides an opportunity to implement any necessary design modifications to ensure the RHMP answers the original and refined questions prior to full resource investment. Many regional scale monitoring programs utilized a limited scope approach in their initial phase of monitoring to verify program design, including the Bight program.

3.1 Pilot Program Objectives

The objectives of the pilot program are to implement the RHMP Core Monitoring on a limited scale to verify the study design. The pilot program will result in data which will be statistically evaluated to set the appropriate frequency of RHMP Core monitoring needed to determine trend analysis. Further, the concept of using a pilot program to verify design elements and understand trend development is supported by the Stormwater Monitoring Coalition's Model Monitoring Technical Committee (SMC).

3.2 Pilot Program Approach

There are two phases to the pilot program. The first phase is to finalize the RHMP Core monitoring program design by filling the information needs. Indicators need to be identified. Threshold levels need to be determined. The preset percentage or proportion needs to be determined. The harbors need to be mapped to identify and characterize strata areas. The second phase is to implement an abbreviated RHMP Core monitoring program to allow for assessment and refinement of the study design.

3.2.1 Phase One – Initial Design Finalization

Steps 1 through 5 below are crucial steps that must be completed prior to implementing the monitoring program and prior to implementing the pilot program. These steps provide the critical elements to ensure the final program design is scientifically sustainable.

3.2.1.1. Step 1 - Acquire and analyze relevant available information. Review of existing information will form the baseline of information regarding existing conditions, identify the appropriate indicator measures, may be utilized to establish thresholds, and will be compiled to set the preset targets or percentage. Relevant information includes the following information that has been collected in the last 10 years, including: data reports as part of compliance monitoring programs, federal and state monitoring efforts, other agency monitoring, or research efforts; information produced by the Southern California Bight Projects; the USEPA Environmental Monitoring and Assessment Program (EMAP) efforts; NOAA's Status and Trends

Program; any readily available information produced by other federal, State, or local programs that would provide appropriate information for the study design refinement. This information will include which indicators were monitored, what thresholds were applied, as well as, recent maps of the harbor areas. A significant step in this process is the organization and analysis of this information. This will require creating a database of information that can be statistically analyzed to establish thresholds and set targets.

3.2.1.2. Step 2 - Complete detailed mapping to verify stratum areas. Identification of all freshwater inputs (including storm drains) as well as all other detailed harbor characteristics must be completed for each harbor to accurately identify and delineate specific stratum within each harbor area. This must be accomplished to allow for both accurate review of historical data for the preset targets development and placement of hexagons for development of the Sampling and Analysis Plan. This step will provide the information needed to delineate each harbor area with the detail required to initiate sample collection.

Preliminary mapping is provided in Figures 1-4. These maps indicate the anticipated strata in each harbor area, exact strata delineation will be required by this step to provide adequate details to finalize the Sampling and Analyses Plan.

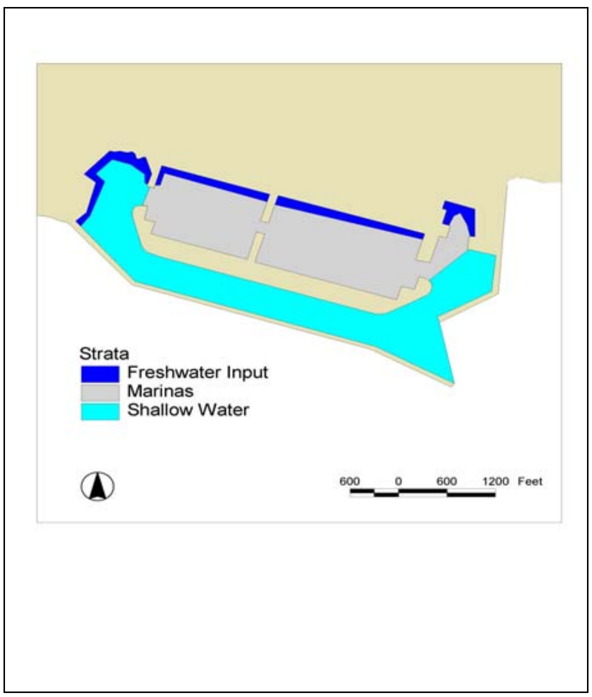


Figure 1. Dana Point Harbor.

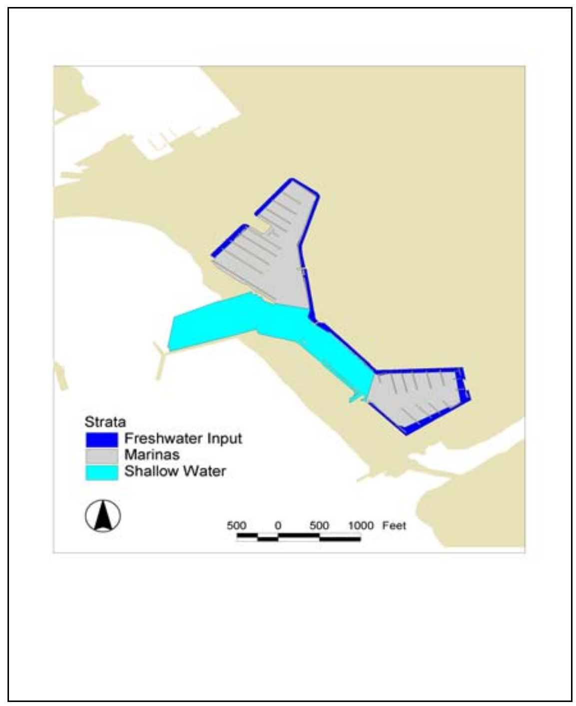


Figure 2. Oceanside Harbor.

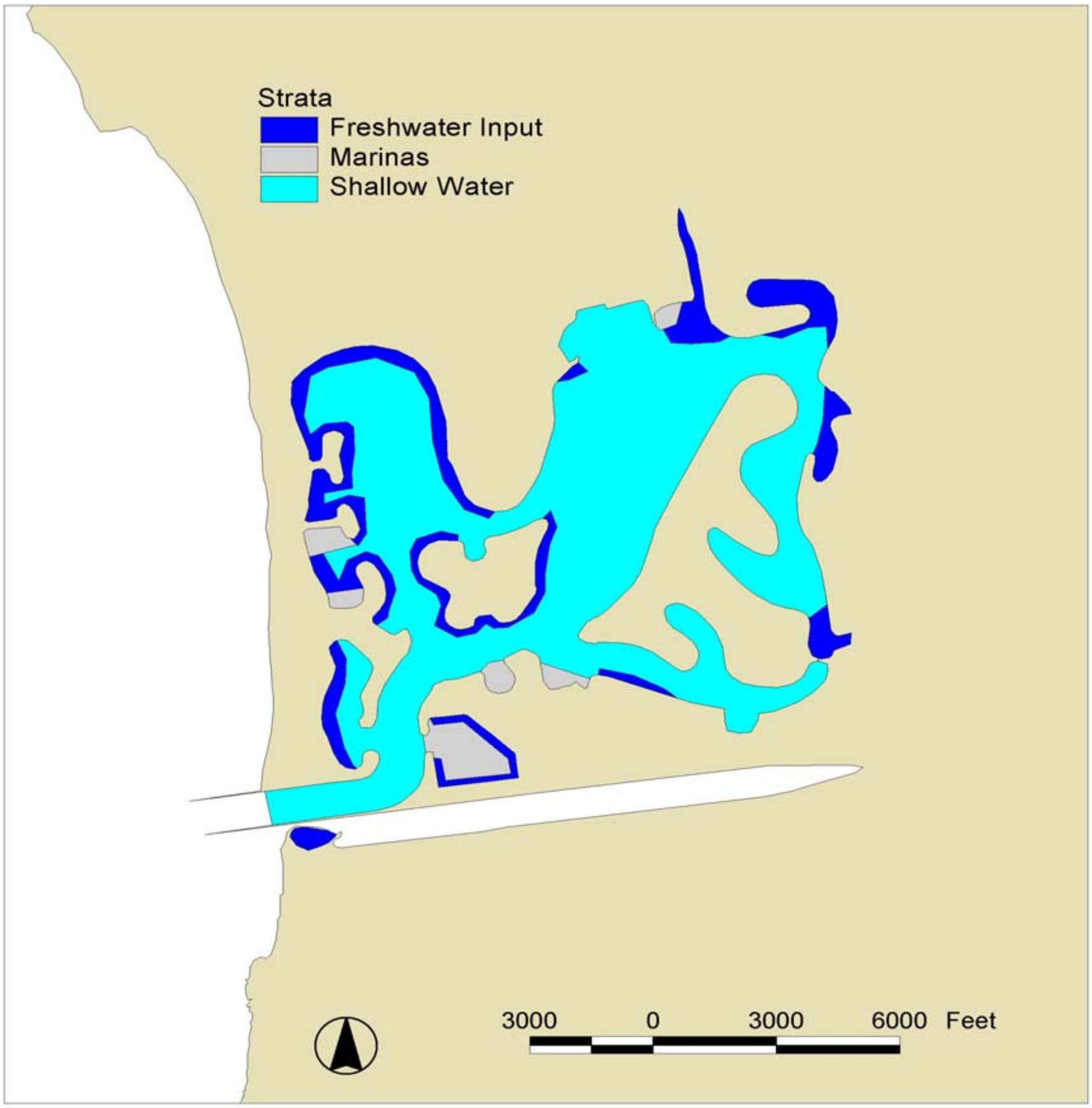


Figure 3. Mission Bay.

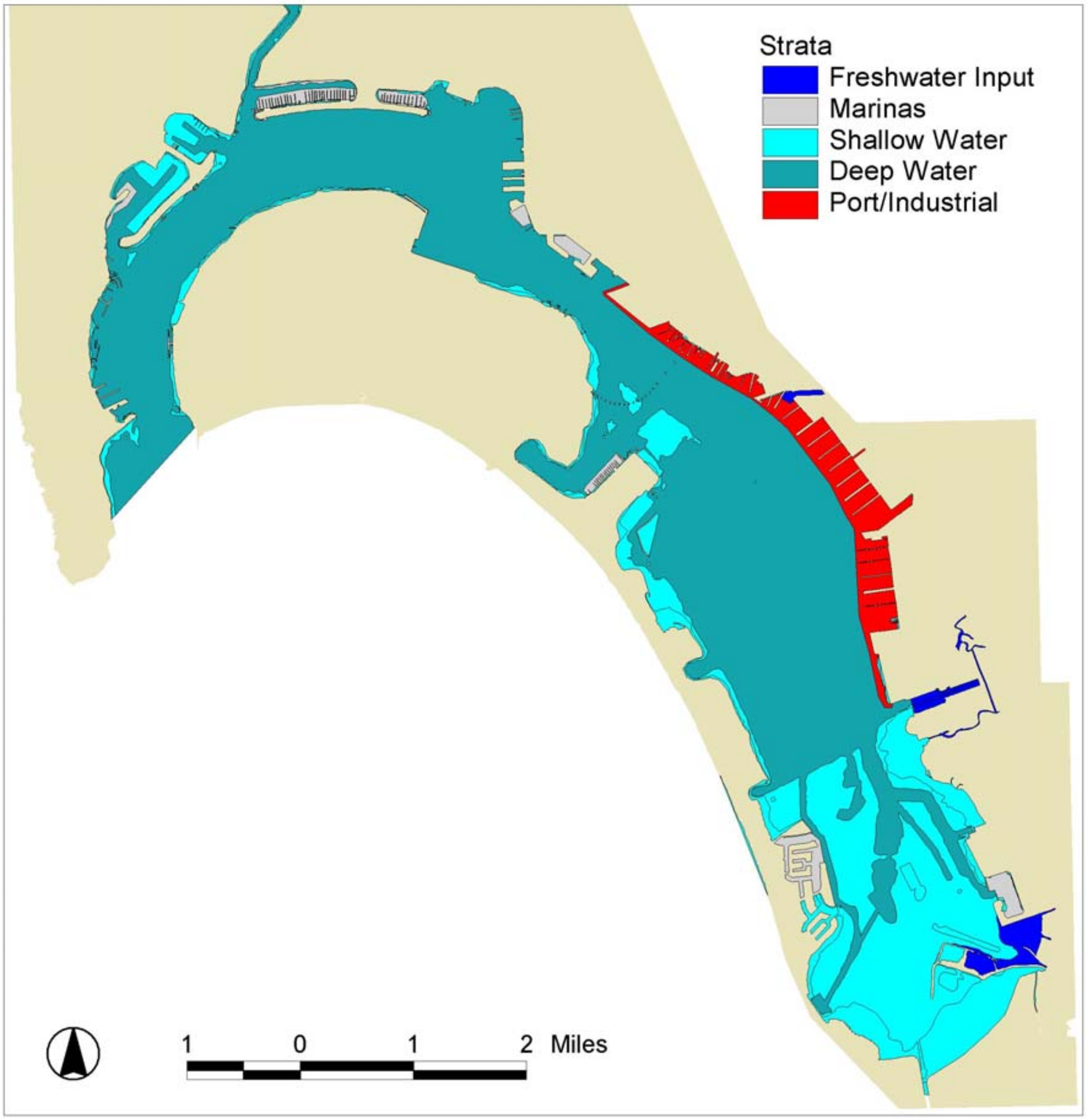


Figure 4. San Diego Bay.

3.2.1.3. Step 3 - Identify the indicators. Select necessary indicators based on the beneficial uses of the specific water body and to ensure program integration with existing monitoring (such as Bight and NPDES monitoring). The identification of the indicators for the monitoring program together with appropriate measurement methodologies and minimum detection limits (for chemical indicators) must be completed. The indicator categories have been identified as water microbiology, chemistry, benthic community, toxicity, and physical indicators. The refinement of the indicators of interest shall be developed through review of the existing monitoring programs to ensure appropriate integration of the data. Existing monitoring programs, including the Bight monitoring program focused studies and NPDES monitoring will be reviewed for indicators, detection limits, and methodologies to establish the details of the monitoring program.

3.2.1.4. Step 4 - Establish the threshold levels. Thresholds for each indicator of interest (chemical, benthic community, toxicity, physical measures) above which there is concern must be established. The thresholds for comparison in this program must be determined prior to program implementation. There are a variety of options and often not a single threshold for a particular indicator. For example with sediment chemistry is it appropriate to use Long et.al. (1995) Effect Range Low (ER-L) and Effect Range Median (ER-M) sediment quality guidelines? Or a reference approach using Bay Protection Toxic Hotspot Program and the Bight ’98 data? Or some other Sediment Quality Guideline benchmark (there are many). A threshold for each indicator must be evaluated and agreed upon prior to program implementation.

3.2.1.5. Step 5 - Establish the preset target proportion or percentage. This design requires determining these percentages by determining the current baseline for the harbors, specifically what proportion or percentage of historical stations in the harbors exceed the threshold levels (Section 3.2.1.4). This would be accomplished through data mining of Bight ’98 and (perhaps) ’03 data (step 1 above). Other available harbor data will also be used if appropriate. Statistical assessment of the existing data will be conducted to determine the baseline of the harbor areas.

3.2.2 Phase Two – Implementing the Pilot Program

Information collected in the pilot program will be assessed to verify the statistical study design and determine the frequency of monitoring needed (i.e. every year, every three years, every five years). The pilot program is proposed to be conducted each summer over a period of three years to develop trend data and evaluate the program. In its simplest form, a trend monitoring design involves repeated sampling over time at the same monitoring areas. The ability of a trend design to detect change depends on:

- The amount of change it is important or necessary to detect
- The timeframe within which decision makers need information about trends
- The variability of the indicator on different time scales, typically shorter term (weekly, monthly) and longer term (yearly)
- The resources available for sampling and analysis.

Developing the specifics of the monitoring design thus involves making a series of tradeoffs among these factors.

The statistical power of a monitoring design is its ability to detect a change of a certain size, if it in fact has occurred. Power analysis, used to estimate the power of a given design, can provide insight into the sampling effort (both in terms of the number of samples per year and the number of years) required to observe trends of different size. In addition, power analyses can reveal important inherent constraints on the ability to detect trends imposed by underlying variability (both within-year and between-year) in the system being monitored. This can provide a realistic basis for establishing both management and monitoring goals, as well as a basis for making tradeoffs in the monitoring design (e.g., between the number of samples collected per year and the number of years over which the trend monitoring will extend).

Figure 5 provides an example of how site-specific power analysis results might be used. In one instance (Figure 5a), trend monitoring would be futile and monitoring resources should be shifted to another site and/or issue. In a second instance (Figure 5b), the only way to improve the design's ability to detect a trend is to increase the number of years to be monitored. In such an instance, the length of time needed to detect a trend must be compared against both the management time horizon (i.e., how quickly is information needed?) and the timeframe over which changes are expected to occur (e.g., how rapidly are BMPs expected to reduce impacts?). In a third instance (Figure 5c), the main way to improve the design's power is to increase the number of samples per year. However, for some situations, there are constraints on our ability to increase the number of samples per year. For example, the period of favorable conditions may be short or personnel and equipment resources may be limiting. In such cases, the monitoring design will have an inherent limit on its ability to detect trends within a given time period. In a final example (Figure 5d), sampling additional times per year and monitoring for more years must be traded off against each other, since increasing both kinds of sampling intensity improves power. Such tradeoffs should be based on both the management time horizon and the timeframe over which changes are expected to occur. Thus, if an answer is not immediately urgent, then the number of samples per year can be reduced and the timeframe extended into the future.

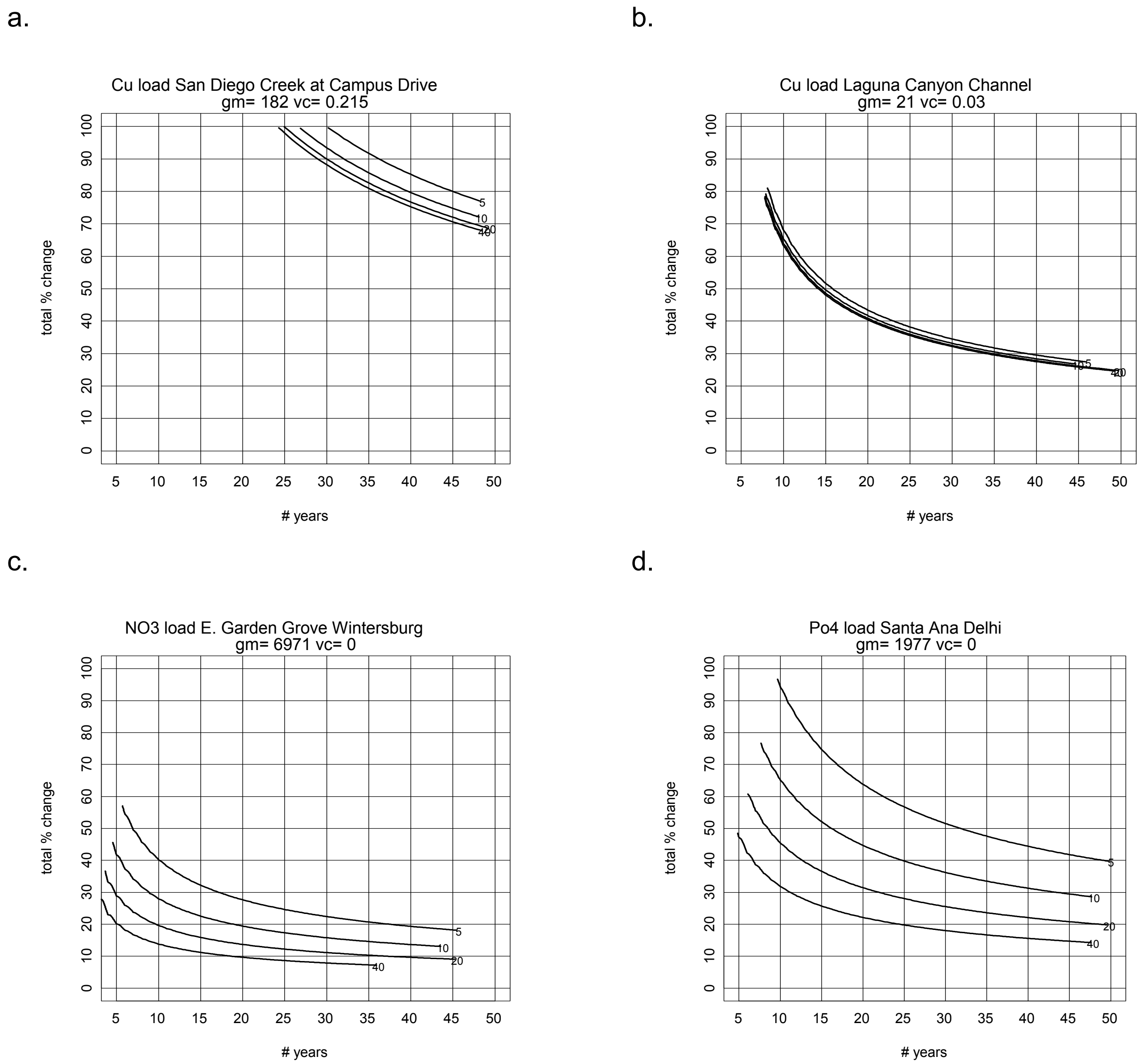


Figure 5. Trend Power Analyses Examples.
(Lines Indicate Number of Samples Collected Per Year)

A three-year Pilot Program to develop adequate information for refining the study design will allow the trade offs discussed above to be more fully understood and decision makers can make informed management decisions regarding the RHMP Core Monitoring Program. The use of a three year period to refine a monitoring design is not unprecedented. The Stormwater Monitoring Coalition (SMC) recommended municipalities desiring to design long-term monitoring studies first monitor for a period of three years and then conduct trend (power) analyses to refine the monitoring program (SMC 2004).

The following subsections detail the steps required to implement Phase II of the Pilot Program.

3.2.2.1 Develop Quality Assurance Project Plan (QAPP) and Sampling and Analyses Plan (SAP). Both the QAPP and SAP should be consistent with Bight program procedures, quality requirements, and methodologies for all indicators to ensure that the results will integrate with Bight information. The Bight program has fully developed protocols that can be adapted to the RHMP. This is not unprecedented, as the SDRWQCB Municipal Stormwater Monitoring Programs Ambient Bay and Lagoon monitoring component followed the Bight '03 protocols. Agencies or consultant firms conducting monitoring shall have participated in the Bight '03 intercalibration or the RHMP Pilot Program shall conduct its own intercalibration to ensure quality and comparability of results. It is proposed that the RHMP QAPP be reviewed by the State Water Resources Control Board.

3.2.2.2 Collect samples as defined in the SAP during summer months. The summer months were selected for the monitoring period because there will be stabilization of the benthic community following winter storms and spring generation of organisms. This timing allows for integration with the Bight program, as Bight monitoring is conducted in the summer months.

The pilot program would only include a limited number of indicators and be conducted at ten stations in two strata. The two strata recommended for the pilot program are fresh water input and marinas. These strata are recommended because they are reasonably anticipated to provide more variability and will provide the most conservative estimate of the number of years needed for monitoring to detect trends. Indicators recommended for monitoring in the pilot program are:

- Water column - Enterococcus, total and dissolved metals, PAHs, turbidity, dissolved organic carbon
- Sediment – metals, PAHs, total organic carbon, grain size, *Eohaustorius estuaries* toxicity
- Benthic community BRI

3.2.2.3 Data storage. Data and metadata will be managed electronically to allow for easy integration with similar datasets and statistical assessment. A standardized data transfer format will be developed similar to the SMC and Bight data transfer formats to allow for sharing of data among agencies.

3.2.2.4 Analyze information. Information collected in the pilot program will be assessed to verify the statistical study design and determine the frequency of monitoring needed (i.e. every year, every three years, every five years) to develop trend data. Power analyses and other statistical tools will be used to assess the pilot program information and determine the ability to detect trends in each indicator category. It is expected that not all indicators will necessarily follow the same pattern; however, this information can provide an indication of the value of long-term monitoring in the San Diego Harbor areas for trend information. How long will it take (years) for trend information to be obtained? What proportion difference will be detectable? This will allow for refinement of the RHMP Core Monitoring Program.

SECTION 4 FOCUSED MONITORING

The focused monitoring portion of the RHMP is designed to identify sources of pollutants and/or to assess the impacts of pollutants on water quality and aquatic resources. Unlike core monitoring, the focused monitoring targets areas with known or suspected pollutant inputs or impaired water quality. The focused monitoring program is directed at those issues noted by the RWQCB in their July 24, 2003 request, namely: areas subject to significant waste loading; areas influenced by significant land or water use patterns (such as industrial, marina, or port); and in areas identified as impaired pursuant to federal Clean Water Act Section 303(d). Focused monitoring studies also evolve from the core monitoring program. The core monitoring program may identify specific questions that can be addressed through focused monitoring within a specific stratum or area. The municipalities have implemented numerous focused monitoring programs (including existing discharge permit compliance programs) that will be integrated into the RHMP to allow a comprehensive understanding of the water quality conditions in each water body.

4.1 Focused Monitoring Objectives

The objectives for the focused monitoring program are to identify the spatial and temporal extent of water quality problems, as well as the geographic and land use/water use sources of pollutants. Additionally, identified impairments are typically related directly to the impairments of the designated beneficial uses of the harbors.

Specific questions that develop from the core monitoring program can be addressed by focused monitoring. Each focused study is developed using a sampling design appropriate to answer the specific focused question(s).

4.2 Existing Focused Monitoring Programs

The RHMP members have identified issues of concern regarding beneficial uses within their respective marinas and have been in the process of developing and implementing focused monitoring efforts to address these issues. The County of Orange, the City of Oceanside, the City of San Diego, and Port of San Diego currently have several programs in place to address the focused studies questions raised in the RWQCB's July 24, 2003 request. The following programs have been identified by each RHMP member as ongoing focused efforts within their respective harbor.

4.2.1 County of Orange

Bight Program Studies: The County of Orange is participating in the Bight '03 Program Studies. This is a regionally based monitoring to assess cumulative impacts of contaminant inputs and to evaluate relative risk among different types of stresses. Components include: 1) coastal ecology, 2) shoreline microbiology, and 3) water quality. This project is conducted on a 5 year cycle.

Ambient Coastal Receiving Water Monitoring: Monitoring is conducted near outlets of storm drains in Dana Point Harbor and Dana Cove during dry and storm water runoff conditions. The indicators included in this study include; aqueous chemistry (nutrients, metals, OP pesticides), aqueous toxicity (sea urchin fertilization, sea urchin embryo development, and mysid survival growth), sediment chemistry (OC pesticides, PCBs, TOC, metals, particle size), sediment toxicity (10-day amphipod survival test, and benthic infaunal analysis). This program is a municipal storm water permit requirement through 2007.

Baby Beach Bacteriological Study: The County conducts weekly sampling throughout the harbor to assess compliance with ocean water contact standards from AB411.

Baby Beach/Ocean Institute Clean Beach Initiative: The project is to mitigate bacteriological contamination and postings at Baby Beach. Three studies will be completed in order to identify the source of bacteria and select appropriate BMPs: a data mining and evaluation study that includes GIS, a bacteriological source tracking study, and a tidal circulation study. Additionally, the Ocean Institute adjacent to Baby Beach has installed stormwater BMPs. The evaluation will characterize the runoff quality leaving the Ocean Institute property for a given storm.

4.2.2 City of San Diego

Bight Program Studies: The City is participating in the Bight ’03 Program Studies. This is a regionally based monitoring to assess cumulative impacts of contaminant inputs and to evaluate relative risk among different types of stresses. Components include: 1) coastal ecology, 2) shoreline microbiology, and 3) water quality. This project is conducted on a 5 year cycle.

Coastal Monitoring: This program is a component of the Municipal Stormwater Permit Order 2001-01. Monitoring provides information regarding which storm drain outfalls at beach locations provide a greater contribution of bacterial contamination at the beach.

Ambient Bay Monitoring: Assessment of receiving waters, sediments, and biota conditions by collecting spatially diverse set of sediment chemistry, biologic, and water chemistry data. This program is a component of the Municipal Stormwater Permit Order 2001-01.

Mission Bay Source Identification Study: This study is a two phased approach to identifying and abating bacterial sources. Phase 1 identified bacteria sources and recommended actions to eliminate them; Phase 2 includes source tracking (DNA tests), fate and transport, and sediment assessment.

Mission Bay (Watershed) Water Quality Study: This study involves the collection of samples at five locations in Mission Bay and 19 locations in its sub-watershed for bacterial analysis. This project is estimated to take between two to three years, starting July 2001 and is expected to be completed by June 2004.

Mission Bay Water Evaluation and Testing (WET) Epidemiology Study: This epidemiological study is conducted at six locations on Mission Bay (Leisure Lagoon, Tecolote Shores, Visitor Center, De Anza Cove, Crown Point Shores, and Bonita Cove) to determine the extent of pathogenic viral contamination to assess human health risks and the connection between water contact and human illnesses, and its frequency; illness surveys and water analysis being conducted by SCCWRP and UC Berkeley on weekends and holidays, Memorial Day – Labor Day 2003. This project is expected to take two years to complete, starting January 2002 with completion on December 2004.

Mission Bay Contaminant Dispersion Study: This study predicts the extent of contamination under a variety of physical conditions, such as tidal and creek influences. Project completed by Scripps Institute of Oceanography.

Mission Bay Water & Sediment Quality Project with University of San Diego (USD): USD and subcontractors collect, analyze, and report on the water quality, sediments, and pelagic and benthic communities in Mission Bay. Monitoring data and analysis are then combined in a comprehensive watershed evaluation. This project started in October 2001 and with 319(h) grant funding provided by the State Water Board, work will continue in fiscal year 2004.

4.2.3 Port of San Diego

Bight Program Studies: The Port is participating in the Bight ’03 Program Studies. This is a regionally based monitoring to assess cumulative impacts of contaminant inputs and to evaluate relative risk among different types of stresses. Components include: 1) coastal ecology, 2) shoreline microbiology, and 3) water quality. This project is conducted on a 5-year cycle.

Coastal Monitoring: This program is a component of the Municipal Stormwater Permit Order 2001-01. Monitoring provides information regarding which storm drain outfalls at beach locations provide a greater contribution of bacterial contamination at the beach.

Dry Weather Monitoring: Jurisdictional monitoring program to assess pollution inputs associated with urban runoff. Port dry weather runoff directly reaches the bay. This program is a component of the Municipal Stormwater Permit Order 2001-01.

Ambient Bay Monitoring: Assessment of receiving waters, sediments, and biota conditions by collecting spatially diverse set of sediment chemistry, biologic, and water chemistry data. This program is a component of the Municipal Stormwater Permit Order 2001-01.

Shelter Island Shoreline Park Bacteria Study: Intense daily sampling over five day periods to determine causes or contributions of high bacteria levels on adjacent beach. Study performed quarterly to assess temporal trends.

TMDL Studies Downtown Piers: Grape Street, and Switzer: Sediment and toxicity monitoring in San Diego Bay near urban runoff inputs to determine sediment toxicity. Objective of project is to reduce sediment toxicity and associated pollutant inputs. This is projected through 2006.

TMDL Studies San Diego Yacht Basin (Copper TMDL): TMDL studies will be required to reduce copper loading in San Diego Bay. The TMDL is pending approval by the Regional Water Quality Control Board (RWQCB). This is projected through 2015.

TMDL Studies Chollas Creek (Diazinon TMDL): Monitoring upstream sites in Chollas Creek to determine pesticide and metals (copper, cadmium, zinc, and lead) loads. Monitoring will consist of both water quality and sediment sampling. No direct sampling in San Diego Bay. This is projected through 2010.

Bay Water Quality Probes: Measures fluctuations (daily, monthly, and seasonal) of physical water quality characteristics in San Diego Bay. This project is ongoing.

4.2.4 City of Oceanside

Bight Program Studies: The City of Oceanside is participating in the Bight '03 Program Studies: This is a regionally based monitoring to assess cumulative impacts of contaminant inputs and to evaluate relative risk among different types of stresses. Components include: 1) coastal ecology, 2) shoreline microbiology, and 3) water quality. This project is conducted on a 5 year cycle.

Coastal Monitoring: This program is a component of the Municipal Stormwater Permit Order 2001-01. Monitoring provides information regarding which storm drain outfalls at beach locations provide a greater contribution of bacterial contamination at the beach.

Ambient Bay Monitoring: Assessment of receiving waters, sediments, and biota conditions by collecting spatially diverse set of sediment chemistry, biologic, and water chemistry data. This program is a component of the Municipal Stormwater Permit Order 2001-01.

Table 4.1 indicates how on-going focused studies relate to RWQCB questions 1-5.

4.3 Proposed New Focused Monitoring – Marina Copper Monitoring

The RWQCB letter requested that the proposed monitoring program include the following: "Identification of significant contributors of waste loading to each harbor. In the case of marinas, docks, moorings, and anchorages, the loading from passive leaching from boat hulls is to be determined." This section describes a design for a focused study to specifically address passive copper leaching from boat hulls. It should be noted that there are numerous other potential sources of copper into harbor areas. Sources of copper into harbor areas include:

- Body wastes (2 mg/Cu/person/day)
- Building and construction materials
- Burning of fossil fuels
- Domestic products
- Natural sources – erosion and run-off of soils
- Non-point – storm water/urban runoff from parking lots/streets due to automotive parts (e.g. brake dust)
- Passive leaching of copper-based antifouling paints (WEF 2002).

The toxicity of copper to marine life is dependant upon the bioavailability of the copper. Copper occurs in the environment in many forms, some forms are toxic and others are not. Copper can be bound to humic and fulvic acids and in a dissolved organic form, copper can be inorganically bound as carbonates, hydroxides, chlorides, and sulfates, or free ionic species. In order to understand the bioavailability of the measured dissolved copper it is important to also measure other indicators that provide a measure of the amount of organic and inorganic copper in the marinas.

4.3.1 Focused Monitoring Objective- Marina Copper Monitoring

The objectives for the focused study are:

1. Identify the significant contributors of copper loading to each marina area.
2. Determine an estimate of the passive leaching from boat hulls.

Table 4.1. On-going focused studies relative to RWQCB questions 1-5.

		Project Description	Timeline	Cost	What are spatial distributions of inputs of pollutants to harbors, how do they vary over time?	Are the waters in harbors safe for body contact activities?	Are fish in the harbors safe to eat?	Do the waters in the harbors sustain healthy biota?	What are the long-term trends in water quality for each harbor?
County of Orange	Bight Program Studies	Regionally-based monitoring to assess cumulative impacts of contaminant inputs and to evaluate relative risk among different types of stresses. Components include: 1) coastal ecology, 2) shoreline microbiology and 3) water quality.	Conducted on 4-5 year cycle	Participant	X	X	*	X	X
County of Orange	Ambient Coastal Receiving Water Monitoring	Monitoring near outlets of stormdrains in Dana Point Harbor and Dana Cove. Monitoring conducted during dry and stormwater runoff conditions. Monitoring includes aqueous chemistry (nutrients, metals, OP pesticides), aqueous toxicity (sea urchin fertilization, sea urchin embryo development, mysid survival-growth), sediment chemistry (OC pesticides, PCBs, TOC, metals, particle size), sediment toxicity (10-day amphipod survival test), and benthic infaunal analysis.	In Permit through 2007	~$80K/yr	X			X	X
County of Orange	Baby Beach Bacteriological Study	Weekly sampling throughout the harbor to assess compliance with ocean water contact standards from AB-411.	Indefinite	~$60K/yr		X			
City of Oceanside	Bight Program Studies	Regionally-based monitoring to assess cumulative impacts of contaminant inputs and to evaluate relative risk among different types of stresses. Components include: 1) coastal ecology, 2) shoreline microbiology and 3) water quality.	Conducted on 4-5 year cycle	Participant	X	X	*	X	X
City of Oceanside	Coastal Monitoring	Provides information regrading which storm drain outfalls at beach locations provide a greater contribution of bacterial contamination at the beach.				X			

Table 4.1. On-going focused studies relative to RWQCB questions 1-5.

		Project Description	Timeline	Cost	What are spatial distributions of inputs of pollutants to harbors, how do they vary over time?	Are the waters in harbors safe for body contact activities?	Are fish in the harbors safe to eat?	Do the waters in the harbors sustain healthy biota?	What are the long-term trends in water quality for each harbor?
City of San Diego	**Bight 03**	Regionally-based monitoring to assess cumulative impacts of contaminant inputs and to evaluate relative risk among different types of stresses. Components include: 1) coastal ecology, 2) shoreline microbiology and 3) water quality.			**X**	**X**		**X**	**X**
	Coastal Monitoring	Provides information regrading which storm drain outfalls at beach locations provide a greater contribution of bacterial contamination at the beach.				**X**			
	Ambient Bay Monitoring	Assessment of receiving waters, sedimetns, and biota conditions by collecting spatially diverse set of sediment chemistry, biologic and water chemistry data.			**X**			**X**	**X**
	Mission Bay Source Identification*	Two phased approach to identifying and abating bacteria sources. Phase 1 indentified bacteria sources and recommended actions to eliminate them; Phase 2 includes source tracking (DNA tests),fate & transport and sediment assessment; $1,300,000 Phase 1: $650,000 - completed; Phase II: $650,000 - started July 2003.			**X**	**X**			**X - Bacteria only**
	Mission Bay (Watershed) Water Quality Study*	Sample at 5 locations in Mission Bay and 19 locations in its subwatershed for bacterial analysis; 2 - 3 years; 7/01-6/04; $362,500.			**X**				
	Mission Bay Water Evaluation & Testing (WET) Epidemiology Study*	Perform an epidemiological study at 6 locations on Mission Bay (Leisure Lagoon, Tecolote Shores, Visitor Center, De Anza Cove, Crown Point Shores, Bonita Cove) to determine the extent of pathogenic viral contamination to assess human health risks and the connection between water contact and human illnesses, and its frequency; ; Illness surveys and water analysis being conducted by SCCWRP and UC Berkeley on weekends and holidays Memorial Day - Labor Day 2003; 2 Years; 1/02-12/04; $1,675,290.			**X - Bacteria, viruses, human health.**			**X - Bacteria, viruses, human health.**	**X - Bacteria, viruses, human health.**

Table 4.1. On-going focused studies relative to RWQCB questions 1-5.

		Project Description	Timeline	Cost	What are spatial distributions of inputs of pollutants to harbors, how do they vary over time?	Are the waters in harbors safe for body contact activities?	Are fish in the harbors safe to eat?	Do the waters in the harbors sustain healthy biota?	What are the long-term trends in water quality for each harbor?
City of San Diego	Mission Bay Contaminant Dispersion Study*	Predict the extend of contamination under a variety of physical conditions, such as tidal and creek influences; Project Completed by Scripps Institute of Oceanography; $400,000.			X - Dispersion modeling.				
	Mission Bay Water & Sediment Quality Project with University of San Diego (USD)*	USD and subcontractors will collect, analysis and report on the water quality, sediments, and pelagic and benthic communities in Mission Bay. Monitoring data and analysis then will be combined in a comprehensive watershed evaluation; Started 10/01-1/04; $200,000; 319(h) grant funding provided by State Water Board for continued work in FY04.			X			X	X - water chemisty, sediment chemistry, toxicity and porewater toxicity.
Port of San Diego	Bight Program Studies	Regionally-based monitoring to assess cumulative impacts of contaminant inputs and to evaluate relative risk among different types of stresses. Components include: 1) coastal ecology, 2) shoreline microbiology and 3) water quality.	Conducted on 4-5 year cycle		X	X	*	X	X
	Coastal Monitoring	Provides information regrading which storm drain outfalls at beach locations provide a greater contribution of bacterial contamination at the beach.	In Permit through 2006			X			
	Ambient Bay Monitoring	Assessment of receiving waters, sediments, and biota conditions by collecting spatially diverse set of sediment chemistry, biologic and water chemistry data.	In Permit through 2006		X				
	Dry Weather Monitoring	Jurisdictional monitoring program to assess pollution inputs associated with urban runoff. Port dry weather runoff directly reaches the bay. Samples collected directly from stormdrains do not directly assess receiving water (San Diego Bay.)	In Permit through 2006		X	X			X

Table 4.1. On-going focused studies relative to RWQCB questions 1-5.

		Project Description	Timeline	Cost	What are spatial distributions of inputs of pollutants to harbors, how do they vary over time?	Are the waters in harbors safe for body contact activities?	Are fish in the harbors safe to eat?	Do the waters in the harbors sustain healthy biota?	What are the long-term trends in water quality for each harbor?
Port of San Diego	**Shelter Island Shoreline Park Baceria Study**	Intense daily sampling over five day periods to determine causes or contributionsl of high bacteria levels on adjacent beach. Study performed quarterly to assess temporal trends.	Jan 2003 - Dec 2003					X	X
	TMDL Studies: Downtown Piers, Grape St, Switzer	Sediment and toxicity monitoring in bay near urban runoff inputs to determine sediment toxicity. Objective of project is to reduec sediment toxicity and associated pollutant inputs.	Projected through 2006		X				
	TMDL Studies: San Diego Yacht Basin	Copper TMDL: Reduce copper loading in San Diego Bay. Implementation plan underway at RWQCB; not yet identified to stakeholders.	Projected through 2015		X			X	X
	TMDL Studies: Chollas Creek	Diazinon TMDL: Monitoring upstream sites in Chollas Creek to determine pesticide loads. Monitoring will consist of both water quality and sediment sampling. No direct sampling in San Diego Bay.	Projected through 2010			X		X	
	Bay WQ Probes	Measure fluctuations (daily, monthly, seasonal) of physical water quality characteristics in San Diego Bay.	Ongoing						X

4.3.2 Overall Sampling Design

The overall sampling design strategy focuses on obtaining a reasonable number of samples throughout the marina area to determine the average concentration of dissolved copper in the area. Further, the sampling design includes indicators that are critical to understanding the biological availability of copper within the marine ecosystem. This focused study is intended to be of short duration (ie: conducted one time) and coupled with information obtained through the core monitoring program and other on-going focused studies to gain a greater understanding of the San Diego Region Harbors.

4.3.2.1 Mapping and Aerial Photographs. Detailed maps of the marina area indicating storm drain inputs and drainage areas will be obtained. Storm drain input information will provide an indication of inputs from storm drain runoff sources of dissolved copper. Recent aerial photographs of the marina dock, mooring, or anchorage area will be obtained to identify vessels within the area. The aerial photographs will be utilized to provide an estimate of vessel surface areas exposed within each marina and used to calculate an estimate of copper loading from those vessels.

4.3.2.2 Sampling and Indicators. Water column samples will be collected at a minimum of five stations within each marina, depending upon the size of the marina area. The number of stations within each marina area will vary based upon the size of the basin to provide a meaningful average concentration of copper within each marina area. At each station discrete samples will be collected at 1 foot below the surface, mid-depth, and 1 foot from the bottom. Indicators for monitoring have been selected to provide an indication of the biological availability of the copper detected within each area. Marina areas shall be sampled along a gradient from the channel opening to the far terminus of the marina area. The indicators recommended for monitoring and the minimum recommended detection limits are included in Table 4.2.

Table 4.2. Focused Marina Study Indicators and Minimum Detection Limits

Water Quality Measurement	Recommended minimum detection limit (mg/L)
Total Copper	0.001 or less
Dissolved Copper	0.001 or less
Total Organic Carbon	0.1
Dissolved Organic Carbon	1.0
pH	--

The measurement of associated indicators listed in the table above can be utilized to estimate the bioavailable fraction of dissolved copper present in the marina.

4.3.2.3 Estimating Copper Leaching From Boat Hulls. Estimates of copper leaching from boat hulls can be approximated by estimating the vessel surface areas exposed using the aerial photographs and calculating the loading using recent research regarding copper leach rates from copper-based antifouling paints (SCCWRP 2003). This information can provide a gross estimate of annual copper loads into marina areas. This information does not, however, provide an indication of the bioavailability of the estimated loads. Bioavailability of copper will be estimated in the marina areas in the sampling program.

4.3.3 Integration With Other Monitoring Programs

This focused study will provide supplementary information to the NPDES measurement and modeling of copper loading from stormwater and urban runoff. It will also supplement information from the RHMP Core Monitoring Program.

SECTION 5 QUALITY ASSURANCE

The RHMP would be developed and implemented to collect high quality monitoring data that would be of the most use to the RHMP members and the RWQCB. This section describes the general quality assurance approach, the need for a quality assurance project plan, and the periodic scientific review of the monitoring efforts.

Quality Assurance (QA) includes activities to ensure that data collected are of adequate quality given the monitoring objectives. QA consists of two separate but interrelated activities – Quality Control and Quality Assessment. Quality Control (QC) activities include standardized sampling collection and processing protocols and requirements for technician training. Quality assessment activities are usually implemented to quantify the quality control procedures.

5.1 Quality Control

QC refers to the technical activities employed to ensure that the data collected are adequate given the monitoring objectives to be tested. The purpose of QC is to control errors that tend to occur in the field, laboratory, or office. This is accomplished by establishing set procedures to ensure that sampling, processing, and analytical techniques are applied consistently and correctly. The Bight program has established standardized procedures for nearly all elements that are included in the RHMP; including field methodologies, laboratory procedures, quality assurance checks, and reporting procedures and data formats. It is recommended that the Bight protocols be followed for the RHMP to allow for data comparability and reproducibility, as well as, cost effectiveness.

QC activities will include both internal and external checks. Internal checks will be a combination of internal test samples, repeated measurements, and standard reference materials. External checks will include evaluation of reproducibility and comparability of tests using inter-laboratory comparisons.

5.2 Quality Assessment

Quality assessment activities are implemented to quantify the effectiveness of the quality control procedures. These activities ensure that measurement error is estimated and accounted for and that bias associated with the monitoring program can be identified. Quality assessment consists of both internal and external checks, including repetitive measurements, internal test samples, interchange of technicians and equipment, use of independent methods to verify findings, exchange of samples among laboratories, use of standard reference materials, and audits.

An effective QA system must begin at the onset of the monitoring program planning process and must continue to be an integral component throughout from program implementation and information dissemination. In this way, the level of uncertainty associated with obtaining the required information can be balanced against the cost of obtaining the data. The QA program should accommodate activities of converting resulting data into useful information and the feedback loops designed to help refine monitoring objectives and approaches.

5.3 Quality Assurance Project Plan

A Quality Assurance Project Plan (QAPP) would be developed for the RHMP as a first step in implementing the program. This QAPP will follow the Bight protocols. The QAPP will contain:

- Descriptions of laboratory and field operations;
- Sampling collection and processing methods;
- Chemical, toxicological, and biological analytical procedures;
- Laboratory data management;
- Measurement quality requirements, including descriptions of representativeness, completeness, comparability, accuracy, and precision;
- Approach for handling data that do not meet the data quality requirements; and
- Reporting requirements.

As a part of the QAPP, a field manual for standardized fieldwork and sample collection shall be developed. It is recommended that the methodologies developed as a part of the Bight ’03 process be adopted for this manual to allow integration of all RHMP information with Bight information.

SECTION 6 DATA MANAGEMENT, DATA EVALUATION, AND REPORTING

Data management, evaluation, and reporting would be high priorities of the RHMP. Too often, limited funds are spent collecting information that ultimately will be of little use due to lack of standardized data management, evaluation, and reporting. The RHMP would include the use of existing data to the extent it can be verified and placed or linked into centralized locations. Any data that are collected as part of the proposed Program will be made available to all stakeholders centrally along with accompanying metadata.

To allow integration with the Bight program, all data will be managed consistent with and in a form that will integrate into the EMAP and Bight data formats.

6.1 Data Management

Information transfer formats will be established to allow for data sharing between agencies. A data transfer format similar to that developed for the SMC and Bight programs will be utilized to allow for sharing of information between those programs.

An electronic database must be established for data analyses, storage, and retrieval of all data and metadata developed as a part of the RHMP. This electronic database will allow information to be assessed and compared to other similar information (i.e., Ambient Bay and Lagoon Monitoring, Bight, EMAP).

6.2 Data Evaluation

Monitoring data must be evaluated in order to make meaningful assessments of the status of the environment. Such evaluations are integral in evaluating the status of the water quality at the time of the study, as well as in evaluating environmental change over time. Conclusions based on a full analysis of monitoring data enable the RHMP members and the RWQCB to assess the condition of the region’s harbor water resources, determine whether the monitoring objectives have been achieved, and ultimately evaluate the success of existing water quality programs.

For the RHMP monitoring data to meaningfully influence decision-making, it is necessary that the data collected be evaluated. It is especially important to develop a consistent set of data evaluation criteria. These criteria will be used to evaluate all the monitoring information collected. Statistical tools including power analyses and ANOVA will be utilized for data evaluation.

SECTION 7 COSTS

This section provides an estimate of the needed funding to fully implement the RHMP, including the estimated costs for the various types of monitoring the proposed in the RHMP, the description of the approach used to estimate costs, and the assumptions made. These costs are estimated and actual costs may vary.

7.1 Existing Programs and Current Expenditures

Current Ambient Programs
The Port, the City of San Diego, the City of Oceanside and the County of Orange all participated in the Bight 03 project during the current year. Members participating in the SDRWQCB Municipal Stormwater Permit (City of Oceanside, City of San Diego, and Port of San Diego) each currently spend $13,000 annually for required ambient monitoring efforts (Ambient Bay and Lagoon Monitoring component). The County of Orange currently spends $80,000 annually for required ambient monitoring under their Municipal Stormwater Permit.

Current Focused Studies
As stated in the RHMP, focused monitoring efforts arise from the identification of water quality impairments, sediment impairments, or the impairment of beneficial uses. Because identification of impairments is an ongoing process, there are currently several water (and/or sediment) monitoring programs that exist today, many of which have intense monitoring requirements projected into the future and have an inherent cost associated with them. As such, RHMP members are contributing a significant amount of funding into the development and implementation of the existing programs.

Table 7.1. Current Estimated Monitoring Expenditures by Program and Jurisdiction.

	County of Orange	City of Oceanside	City of San Diego	Port of San Diego	Totals
Bight '03	$75,000	$45,000	$50,000	$50,000	**$220,000**
Coastal Monitoring	see Baby Beach	$10,000	$20,000/yr	$10,000/yr	**$40,000+**
Ambient Bay Monitoring	$80,000/yr	$13,000/yr	$13,000/yr	$13,000/yr	**$119,000**
Dry Weather Monitoring	n/a	$30,000	$95,000/yr	$10,000/yr	**$135,000**
Mission Bay Source Identification	n/a	n/a	$1,300,000	n/a	**$1,300,000**
Mission Bay (Watershed) Water Quality Study	n/a	n/a	$362,000	n/a	**$362,000**
Mission Bay WET Epidemiology Study	n/a	n/a	$700,000	n/a	**$700,000**
Mission Bay Contaminant Dispersion Study	n/a	n/a	$400,000	n/a	**$400,000**

	County of Orange	City of Oceanside	City of San Diego	Port of San Diego	Totals
Mission Bay Water & Sediment Quality Study	n/a	n/a	$200,000	n/a	**$200,000**
Shelter Island Bacteria Study	n/a	n/a	n/a	$80,000	**$80,000**
TMDL Studies: Downtown Piers, Grape St., Switzer	n/a	n/a	n/a	$300,000	**$300,000**
TMDL Studies: San Diego Yacht Basin	n/a	n/a	n/a	to be determined	**to be determined**
TMDL Studies: Chollas Creek	n/a	n/a	to be determined	to be determined	**to be determined**
San Diego Bay Water Quality Probes	n/a	n/a	n/a	$30,000	**$30,000**
Baby Beach Bacteriological Study	$60,000	n/a	n/a	n/a	**$60,000**
Baby Beach Ocean Institute Clean Beach Initiative	$575,000	n/a	n/a	n/a	**$575,000**
Totals	**$790,000**	**$98,000**	**$3,140,000**	**$493,000**	**$4,521,000**

7.2 RHMP Core Monitoring Program Estimated Costs

To understand the economics of the proposed program, an estimated cost was developed as a reference point. These costs were developed based upon 2003 project work conducted by MEC as a Bight contractor and represent best estimates based upon current available data and the preliminary program design. This estimated cost is for conducting the RHMP Core Monitoring Program as previously described.

7.2.1 Phase I Pilot Program Estimated Costs

Required Development Activities	**Cost Estimates – Year 1**
Establish baseline for model (data mining and analyses) Statistical design refinement Mapping	$40,000 - $80,000
Workplan and QAPP	$10,000 - $20,000
Estimated Program Development Costs – Year 1	**$50,000 - $100,000**

7.2.2 Phase II Pilot Program Estimated Costs

Program Implementation Costs	Annual Cost Estimates – Years 2-4
Program Management	$15,000 - $30,000
Field Sampling (2 strata /10 stations)	$45,000 - $50,000
Analytical testing 2/10	$100,000
Data analyses, management and reporting	$30,000 - $50,000
RHMP Core Pilot Program Cost (2 strata/10 stations each) Years 2-4 (annual costs)	**$190,000 - $230,000**
Total Pilot Program Cost Over 3 years (Years 2-4)	**$570,000 - $690,000**

7.2.3 RHMP Core Monitoring Program Estimated Costs

Program Implementation Costs	Cost Estimates – Year 5
Program Management	$30,000 - $50,000
Field Sampling (5 strata /15 stations) or Field Sampling (5 strata/10 stations)	$72,000 - $78,000 or $54,000 - $59,000
Analytical testing 5/15 or Analytical testing 5/10	$392,000 $264,000
Data analyses, management and reporting	$60,000 - $80,000
Core Program Cost (15 stations/strata) (without fish Q3)	**$554,000 - $600,000**
Core Program Cost (10 stations/strata) (without fish Q3)	**$408,000 - $453,000**

Additional Program Costs for Fish Q3	Additional Program Cost Estimate – Year 5
Field sampling – trawls	$68,500 - $90,000
Chemistry (PCBs, Pesticides, select metals, lipids)	$95,400 - $159,000
Data Management Effort	$18,000 - $22,000
Additional cost for fish Q3 (every 5-10 years)	**$181,900 - $271,000**

7.3 Focused Copper Study Estimated Costs

Estimated costs for the focused copper study make several assumptions and cost estimates may require adjustments based upon the actual number of stations sampled. The following costs are estimates per marina, however, an economy of scale can be achieved by monitoring at multiple marina areas. The cost economies would be realized in program management, loading estimation, data analyses, management and reporting.

Program Implementation Costs	Cost Estimates Per Marina
Program Management (includes QAPP and SAP)	$10,000
Field Sampling 5 stations 3 depths	$8,000 - $13,000
Analytical testing 5 stations 3 depths	$4,000
Data analyses, management and reporting	$5,000
Mapping, aerial photographs and estimate of loading from copper-based boat paints	$7,500
Per marina estimate	**$34,500 - $39,500**

SECTION 8 SCHEDULE

A proposed project schedule to demonstrate timelines is provided as illustration of project timing. Initiation of this proposed RHMP is dependant upon securing funding sources.

Activity	**Duration**
Obtain funding	on-going
Phase I Pilot Program	9 – 12 months
Phase II Pilot Program	36 months, annually in summer
Revise Program Design	1-3 months
Initiate Core Monitoring Program	At specified design frequency

If funding is obtained in 2004, it is possible that Phase I of the Pilot Program could be completed prior to summer 2005 to allow for Phase II to be implemented Summer 2005 through 2007. Revision and refinement of the Core Monitoring Design could be accomplished prior to summer 2008 to allow for coordination of the RHMP Core Monitoring with the Bight '08 program.

If adequate funding is obtained, the focused copper study could be implemented concurrent with the first year of the Phase II Pilot Program, allowing for an economy of efforts in the management and reporting tasks.

SECTION 9 REFERENCES

Bernstein 1999. B.B. Bernstein, M.J. Allen, J. Dorsey, M. Gold, M.J. Lyons, G.A. Pollock, D. Smith, J.K. Stull, G.Y. Wang, Compliance Monitoring in a Regional Context: Revising Seafood Tissue Monitoring For Risk Assessment. Ocean and Coastal Management. 1999.

Cohen, J. 1977. Statistical Power Analysis for the Behavioral Sciences, Revised Edition. Academic Press, New York. 474 p.

Commission of Southern California Coastal Water Research Project. Bight '98 Steering Committee. 1998. Southern California Bight 1998 Regional Marine Monitoring Survey (Bight '98) Coastal Ecology Workplan. 67 p.

SMC, 2004. Model Stormwater Monitoring Program for Urban Runoff Programs, A report from the Stormwater Monitoring Coalition's Model Monitoring Technical Committee. Review Draft December 2003.

WEF 2002. Water Environment Federation Workshop – Copper Biotic Ligand Model. Chicago, Illinois.

SCCWRP, 2003. Schiff, K., D. Diehl and A. Valkirs. 2003. Copper emissions from antifouling paint on recreational vessels. Southern California Coastal Water Research Project, Westminster, CA.

APPENDIX A

Analytical Design

Technical Report– Harbor Monitoring Program for San Diego Region
San Diego Bay, Mission Bay, Oceanside Harbor and Dana Point Harbor
APPENDIX A – ANALYTICAL DESIGN

1.0 INTRODUCTION

Some of the major objectives of the Harbor Monitoring Program are to:

1) develop a sampling approach capable of identifying sediment and water quality status and trends,
2) determine the spatial distributions of inputs of pollutants to harbors and assess how they vary over time,
3) assess whether the waters and sediments in the harbors sustain healthy biota, and
4) design a program that is compatible with the Southern California Coastal Water Research Project (SCCWRP) Bight Program.

The purpose of this appendix is to present the design of a cost-effective monitoring program, whose power for detecting sediment and water quality is understood, and that will be compatible with the Bight Program. The program presented here answers a concise list of clearly stated and meaningful questions. These questions, because they are simple and straight-forward, provide better design guidance and their answers are more readily understood by managers and the public.

The first set of questions deal with the characteristics of and differences among strata in space and time. A stratum, for purposes of the present program, is defined as a type of harbor environment (e.g. marina) that is common across all (or most) harbors. Harbors can be divided into a number of strata, such as deep open waters, shallow open waters, marinas and port/industrial areas, and outfalls/streams. Every harbor will not (and for statistical treatment, does not have to) possess each of the strata. Once the strata have been established, sampling sites are randomly selected within each stratum for comparison among strata. This is known as a stratified random design, which was utilized by SCCWRP in the Bight 2003 program. The questions that can be answered by using this design are:

1. How much of the area of each stratum is above or below relevant benchmarks?
2. How has the area of each stratum above/below relevant benchmarks changed over time?
3. What is the area-weighted average of relevant indicators in each stratum?
4. How has the area-weighted average measure of relevant indicators in each stratum changed over time?
5. How different are the average values of relevant indicators in different strata?
6. How has the degree of difference between strata changed over time?

Relevant indicators for purposes of the Harbor Monitoring Program refer to selected measures of sediment or water column chemistry (concentrations), benthos (abundance or indices), and toxicity (indices, e.g., LD-50s or TUs). This triad approach is described in the main body of this report.

Within the framework of the stratified random approach, there are several statistical tools that may be used to assess the harbors, including binomial assessments, regression analyses,

Analyses of Variance (ANOVAs), and Repeated Measure Analysis of Variance (RM-ANOVA). The binomial design allows for descriptive assessments of the proportion of the total stratum area that is above a relevant threshold for a given constituent or measurement. The design also provides the framework to determine area-weighted concentrations of constituents of concern, and indices of relevant indicators in a stratum. Regression analyses are used to assess whether these proportions and area-weighted averages change over time. ANOVAs are appropriate for testing explicit hypotheses regarding differences between strata, while RM-ANOVAs can track the differences between strata over time.

Designs for the binomial approach and the regression analysis will be described in the following sections. These two designs are the limiting factors in determining the power of the Harbor Monitoring Program, i.e., its ability to detect differences or changes should they occur. If power is sufficient for these approaches, it should also be sufficient for ANOVA and RM-ANOVA.

2.0 <u>THE BINOMIAL DESIGN</u>

The first set of issues addressed in the binomial design is directed at assessing the state of a stratum without respect to differences among harbors (questions #1 and #2 outlined above). That is, it determines the proportion of stations within a stratum that exceed a relevant threshold of concentration or abundance of an indicator of interest. Or, stated another way, what proportion of the total stratum area is above a relevant threshold? This assessment is irrespective of harbors and, just as the SCCWRP program, is not designed to address whether a given stratum differs between harbors. Questions 3 and 4 of the binomial design outlined above refer to determining area-weighted averages and comparisons of concentrations, abundances, or indices. For instance, for a given constituent, the area weighted average would be the sum of concentrations for that constituent times the sub-area of the stratum that each station represents, divided by the total stratum area.

The use of strata is a key element of the SCCWRP Bight (and the EMAP) program. Statistically, the design requires an approach based on the binomial model addressing proportions. A proportion is a special case of an arithmetic mean, in which the measurement scale has only two possible values: zero for the absence of a characteristic and one for its presence. Thus, one can describe a population as having a proportion of sampled stations in a stratum either over or under a threshold value (the level designating the relevant benchmark).

In the SCCWRP program, no relevant threshold and no target proportion is designated *a priori*. This leads to a relatively inefficient design (that in a sense explores all proportions) that requires numerous replicate samples (stations) to achieve statistical power. It has been quoted numerous times (e.g., Commission of SCCWRP, 1998) that from 30-40 samples per stratum are needed to achieve confidence. Furthermore, the design used in the SCCWRP program could potentially open the door to subjective, *a posteriori* (after the fact) decisions on what might be considered a relevant threshold based on the “look” of the newly measured data.

Alternatively, we can establish benchmarks that we really believe *a priori* are relevant thresholds (described as concentrations for chemicals and abundance or indices for fauna) of various indicators important to sediment and water quality or harmful to flora and fauna. Values can be obtained from Basin Plans, the California Toxics Rule, the Ocean Plan, or other sources. Once the relevant thresholds have been established, data from large-scale studies, such as Bight 1998 and Bight 2003 can be used to establish the proportion of stations exceeding that relevant threshold for each indicator of interest. Let us call this proportion P, the Target Proportion.

Through this process, we have defined two criteria: The Relevant Threshold and the Target Proportion. This would be done for each indicator of interest.

Having established *a priori* Relevant Thresholds and the Target Proportion, the binomial statistical design becomes a single sample of n observations (Cohen 1977). The model predicts that the proportion, P, of randomly selected stations in a stratum is equal to c. The value of c can be set at various levels, such as the proportion of stations in harbors (or a marina stratum, or port stratum, etc.) sampled in Bight 1998 that exceeded a specified threshold. Alternatively, c can be selected from the Bight 1998 reports to be an important inflection point on the cumulative probability curve or an indicator of interest (chemical concentration, faunal abundance, or faunal index). We ask whether P, the number of stations that exceed that threshold in the new Harbor Monitoring Program, divided by the total stations in that stratum is larger than c. The null hypothesis, H_o, is $P = c$. The alternative hypothesis, H_a, is $P > c$. This is a one-sided test since we are not concerned for the moment if $P < c$. (We can track $P < c$ over time later with regression analysis.)

2.1 The Development of the Number of Replicate Samples (i.e., Monitoring Stations) Needed Per Stratum

The establishment of a one-sided test of $P \geq c$ will allow for sufficient power to detect differences from "c" with acceptable statistical error with far fewer samples (stations) per stratum. The following is an example of the statistical development of n, the number of replicate samples needed per stratum.

Let us assume that **c** is 0.1 (e.g., 10% of the harbor stations in Bight 98 exceeded 5 µg/g sediment level), the selected relevant threshold. These two pieces of information (10% and 5 µg/g) form our benchmark. To determine the number of samples necessary to show a significant difference between P and c, a power analysis is first conducted. We ask how many stations, n, must there be per stratum to provide an approximately 80% chance (or probability) of detecting a future proportion (P1) that is significantly greater than 0.10. The probability of 80% (also known as the Power) can be set at any level, but 80% is most often used.

Using the vernacular and definitions of Cohen (1977) to establish a scale of equal units of detectability, an arcsine transformation is first applied to the proportions.

Phi_1 = the arcsine transformation of P1 = 2 arcsine $P1^{1/2}$, and
Phi_c = the arcsine transformation of c = 2 arcsine $c^{1/2}$.

Using Phi's, equal distances between Phi's are equally detectable. Thus an effect size index (the degree of departure from the null hypothesis, P = c) can be established using these parameters, where the effect size index, $h_2 = Phi_1 - Phi_c$.

A table is set up, which tracks the parameters needed to assess n, the number of samples needed to achieve a desired power (columns) and covers various P1s greater than c (rows). Table A-1 is presented below as an example.

Table A-1. The number of samples needed to achieve a desired power for various P1s at c = .10.

P1*	c	Phi_1	Phi_c	$h_2 = Phi_1 - Phi_c$	Table h**	Number of Samples***	Number of Samples***	Number of Samples***
						Power=.80	Power = .75	Power = .70
.13	.10	.738	.644	.09	.13	>100	>100	>100
.17	.10	.850	.644	.21	.30	100	84	72
.21	.10	.952	.644	.31	.44	46	39	32
.25	.10	1.047	.644	.40	.57	28	25	21
.29	.10	1.137	.644	.49	.69	19	16	14
.34	.10	1.245	.644	.60	.85	13	11	9
.39	.10	1.349	.644	.71	1.00	9	8	7
.44	.10	1.451	.644.	.81	1.15	7	5	5

* From Cohen (1977) Table 6.2.1 with P_2 = 0.1.

** Cohen's tables are developed for "h", effect size index for two sample tests; for look up value of "h" in Cohen's tables for one sample test (P vs c, a constant), use 1.414 h_2.

***Interpolated from Cohen (1977) Table 6.3.3: Power of Normal Curve Test of $P_1 = P_2$ via Arcsine Transformation at alpha (Type 1 error) of .10.

From Table A-1 it can be seen that with seven stations, for example, there is an 80% chance (Power = 0.8) of detecting a difference between the Target Proportion of 10% of the stations (P of 0.10) and an actual proportion of 44% (P1 = .44) of the stations in the proposed Harbor Monitoring Program. If 100 stations are monitored, there is an 80% chance of detecting a difference between the target 10% of the stations (P of 0.10) and an actual proportion of only 17% of the stations in the proposed Harbor Monitoring Program.

Power analysis is primarily relevant to planning of experiments and thus with the alternate-hypothetical Effect Size. Once the sampling is performed and the data are in, attention turns to the assessment of the null hypothesis in the light of the Harbor Monitoring data. For the actual significance testing, the Effect Size Index (h) is redefined so that its elements are observed sample statistics rather than hypothetical population parameters. Table 6.3.3 of Cohen gives h_c, the value that must be exceeded for two-sample tests (comparing two populations). For our one-sample test (comparing the Harbor Monitoring Program Results to a constant, the Target Proportion), the table lookup value must be multiplied by .707 (i.e. the square root of ½; see Cohen, 1977, p. 212 formula (6.5.6)). Using this adjusted value h_c, we can determine P1, the proportion of stations in a stratum that exceed the threshold out of a total of 10 stations that would result in a significant test result (i.e. P1 = c would be rejected).

In Table 6.3.3, h_c is denoted as .573 for n = 10 samples (stations). Therefore the Effect Size is .707 x .573, or .405. Given, that $h_c = Phi_1 - Phi_c$, and Phi_c is .644 (arcsine transformation of 0.1; Table 6.2.2 for c = P = .1), Phi_1 = .405 + .644 = 1.049. Back transformation of the arcsine transformation gives a P1 of .25. Thus, if 25% of the stations exceed the threshold concentration (or 25% of the area of a stratum exceeds the threshold level) the proportion is significantly different from 10%. Thus, once the new harbor monitoring data are acquired, the test of significance becomes more sensitive (i.e., P = 25% in the actual test vs. P = 39% from the power analysis).

In summary, if 10 stations are used per stratum:

- There is a 10% chance of saying the proportion of stations exceeds the Target Proportion of 10%, if in fact that is not the case. This is the type-1 or alpha error,
- There is a greater than 70% chance of saying the proportion of stations exceeding the Target Proportion of 10%, if in fact it was (the latter if the actual proportion was 39% or greater). This is the power, and
- When the new data are available and tested, a measured proportion of 25% of stations exceeding the relevant threshold will result in a statistically significant difference from the Target Proportion of 0.10.

2.2 Relationships Between Power And Detection Levels

Detection levels of statistically significant departures from a Target Proportion of 0.10 is shown in Figure A-1 for 10 stations per stratum and in Figure A-2 for 15 stations per stratum. The ability to detect small proportional shifts in stations exceeding a relevant threshold increases with increasing replication. At a Power of 80% for example, a proportion of 0.32 is significantly different than a Target Proportion of 0.10 with an n of 15, while a proportion of 0.38 is needed for an n of 10.

The manner in which the detection level of the alternative population with Proportion P changes with increasing stations per stratum for different Powers is shown in Figure A-3. The message from the figure is that there is a linear improvement from n = 9 to n = 15 after which gains are smaller. We suggest that, because of the large cost of increasing n (the number of stations per stratum), the optimum allocation would seem to call for using a Power of .70 (probability of detecting a difference, should one occur) at 10 stations per stratum. In this scenario, there would be a good chance (70%) of detecting a shift from a Target Proportion of 0.10 to a proportion of 0.35.

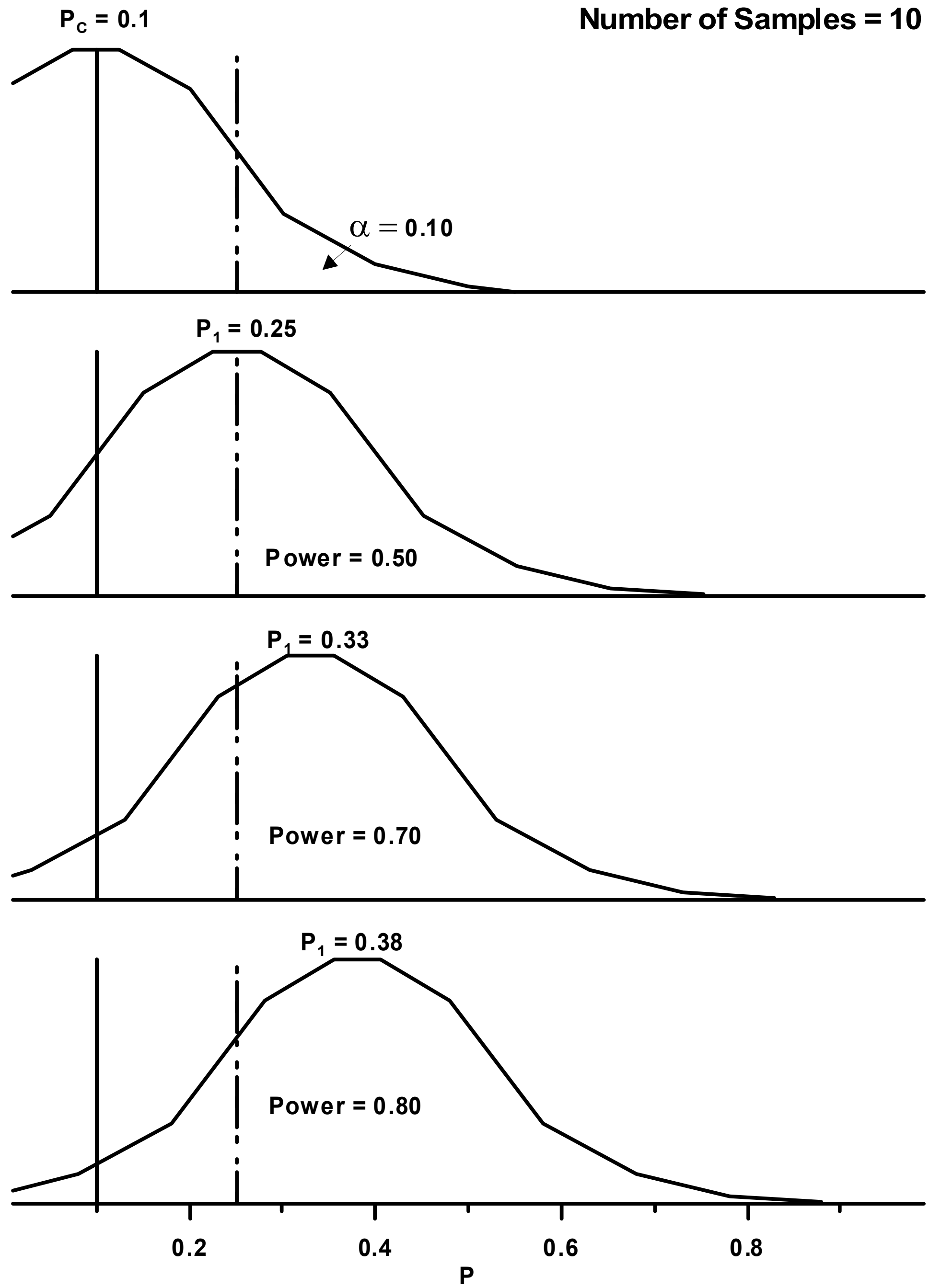


Figure A-1. The power of detecting a population with a proportion, P1, of stations exceeding a relevant threshold if there are 10 stations per stratum in the proposed Harbor Monitoring program and the Target Proportion, Pc, is 0.1.

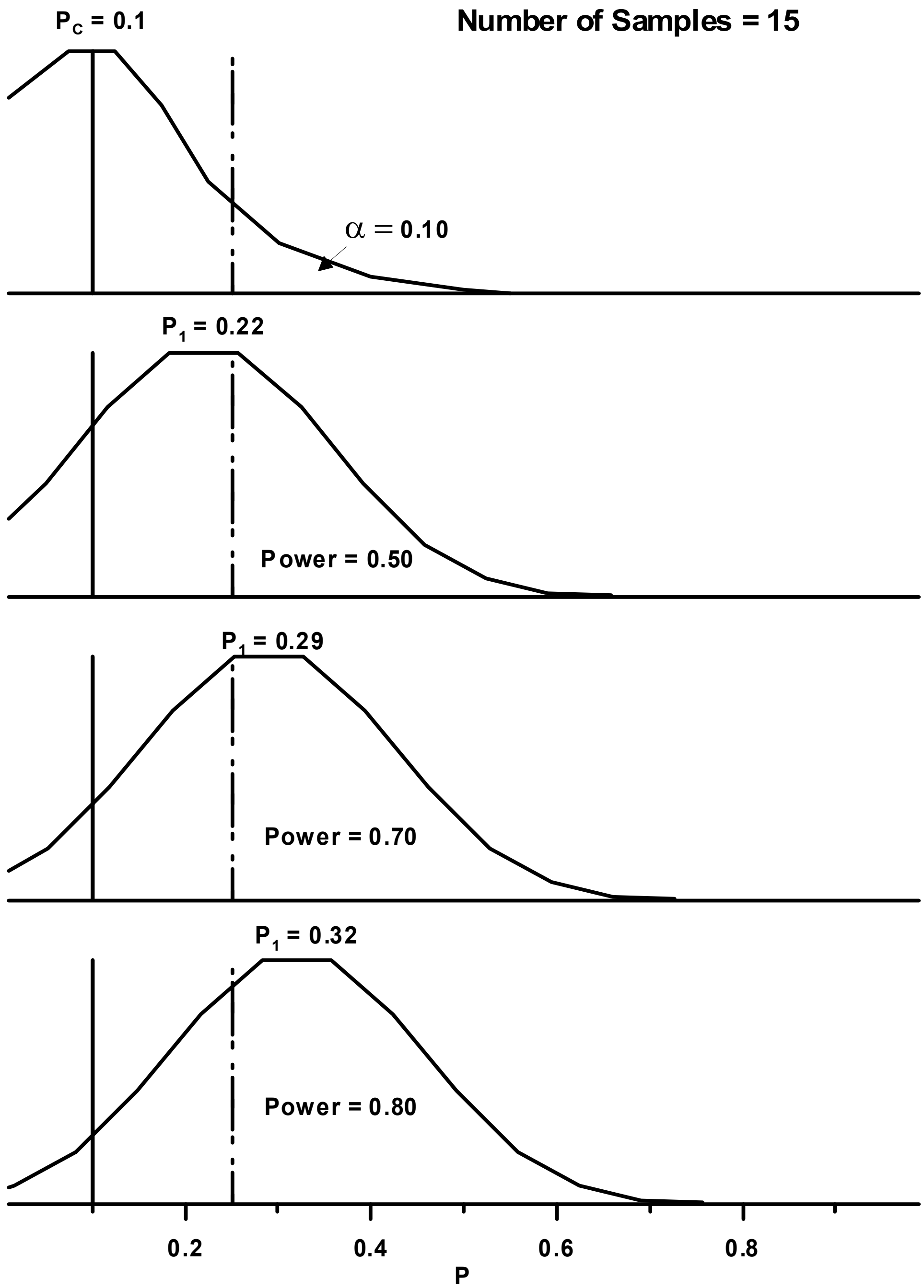


Figure A-2. The power of detecting a population with a proportion, P1, of stations exceeding a relevant threshold if there are 15 stations per stratum in the proposed Harbor Monitoring program and the Target Proportion, Pc, is 0.1.

2.3 A Second Example To Demonstrate The Power Analysis Results For A Target Proportion of 0.50.

The power analysis was repeated under conditions where the Target Proportion P is 0.50 (i.e., 50% of the stations in a stratum are expected to exceed a relevant threshold) (Table A-2). The results show that power remains about the same. In other words, it takes a difference in proportion of about 0.30 from the Target Proportion to achieve significance. With about 10 stations sampled for that stratum, there is an 80% chance of detecting a significant increase from the Target Proportion if the theoretical population has a proportion of 0.8 (i.e., 8 out of the 10 stations would exceed the relevant threshold). This can be seen from interpolating between the row with P1 = .82 and P1 = 0.78.

Table A-2. The number of samples needed to achieve a desired power for various P1s at c = .50.

P1*	c	Phi_1	Phi_c	$h_2 = Phi_1 - Phi_c$	Table h**	Number of Samples***	Number of Samples***	Number of Samples***
						Power=.80	Power = .75	Power = .70
.60	.50	1.777	1.571	.2	.28	>100	90	>100
.65	.50	1.875	1.571	.3	.42	52	45	38
.69	.50	1.961	1.571	.4	.57	29	24	20
.74	.50	2.071	1.571	.5	.71	1	16	13
.78	.50	2.165	1.571	.6	.85	13	11	9
.82	.50	2.265	1.571	.7	.99	9	8	7
.86	.50	2.375	1.571	.8	1.13	7	6	5
.89	.50	2.465	1.571	.9	1.27	5	4	4

The relationship between the detection level of the alternative population with Target Proportion P and the number of stations per stratum for the two different powers is shown in Figure A-4. The relationship is nearly the same in Figure A-4 as it is in Figure A-3. There is a linear improvement from n = 9 to n = 15, after which gains are smaller. We suggest that because of the large cost of increasing n (the number of stations per stratum), the optimum allocation would be 10 stations per stratum. In this scenario, there would be a good chance of detecting a shift from a Target Proportion of 0.50 to a population with a proportion of 0.75 of stations exceeding a threshold.

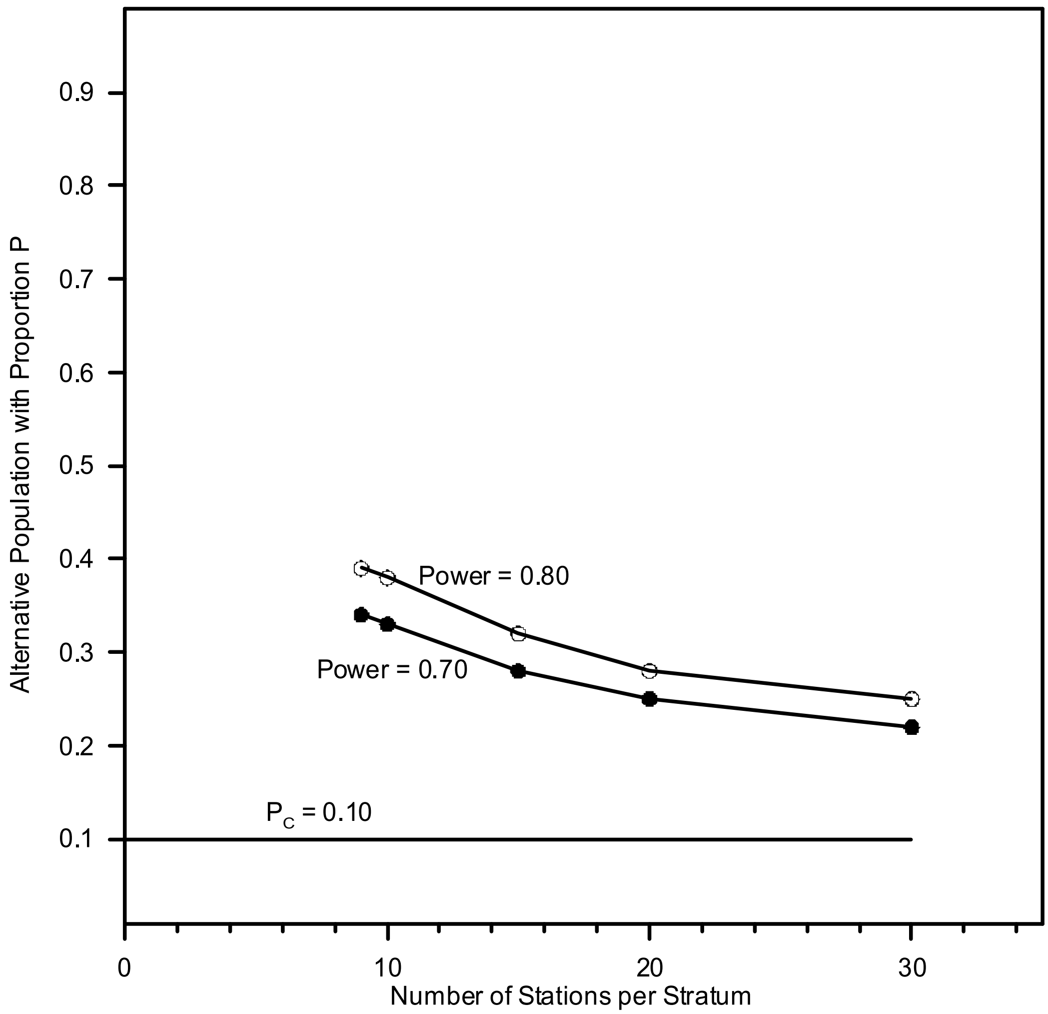


Figure A-3. The proportion of stations that must exceed the Target Proportion, Pc, is 0.10 for powers of 0.7 and 0.8 as a function of the number of stations per stratum.

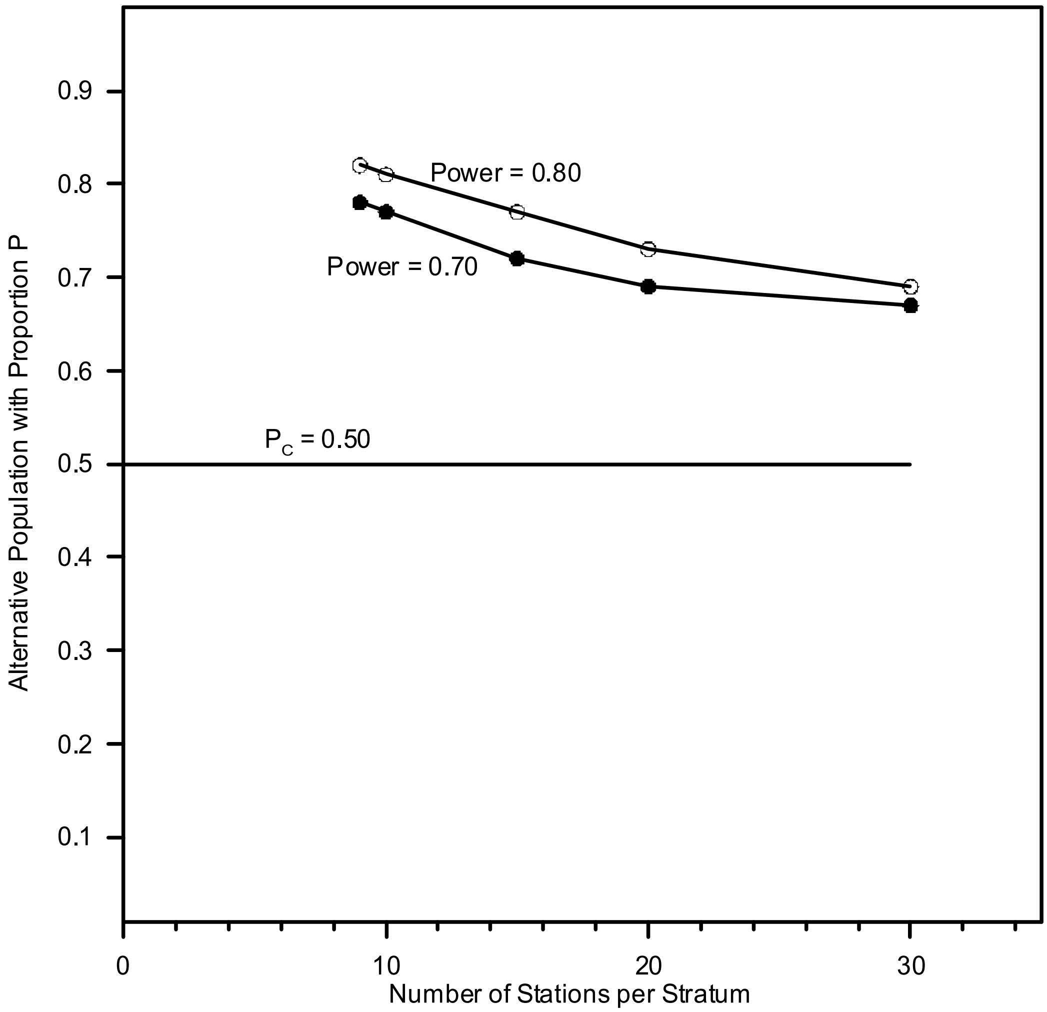


Figure A-4. The proportion of stations that must exceed the Target Proportion, Pc, is 0.50 for powers of 0.7 and 0.8 as a function of the number of stations per stratum.

3.0 REGRESSION ANALYSES

From the perspective of the binomial approach, one probability value becomes available from each stratum each time the Harbor Monitoring Program is conducted. The value represents the percentage of total stations in a stratum that exceeded an established threshold. These percentages can be tracked through time using regression analyses to assess whether they decrease (the proportion of exceedances become less).

Power analyses were done on the regressions which represented two types of potential changes that might be encountered:

- Case 1. Probabilities dropped from 0.50 (50% of stations had exceeded the relevant threshold initially) to 0.10 (10% exceedances).
- Case 2. Probabilities dropped from 0.20 to 0.10.

The question asked was how many sampling periods would be needed to detect these changes with 10 or 15 random stations per stratum. In these analyses it was assumed monitoring was conducted once per year. If sampling is done on a less frequent basis the results should be interpreted as the number of monitoring periods (rather than years) necessary to see the change.

It should be noted that this analysis is a best case scenario. This is because the variability we will be dealing with has two components, the variance associated with the binomial design and the variance associated with time. The former variance is based on the number of stations per stratum and we can calculate that from our assumptions. The latter (year to year variability) we have no information on at this time; the information can only be obtained from a pilot program. The results reported here assume zero variability in time (percentages decrease in monotonically smooth fashion, which is of course somewhat unrealistic).

Table A-3. Regression Power at alpha = 0.1.

Probability of Exceedance of Relevant Threshold	Number of Stations (n) per Stratum	Number of Years	Power
From P=0.5 to P=0.1	10	3	.30
From P=0.5 to P=0.1	15	3	.37
From P=0.5 to P=0.1	10	4	.46
From P=0.5 to P=0.1	15	4	.56
From P=0.5 to P=0.1	10	5	.58
From P=0.5 to P=0.1	15	5	.70
From P=0.5 to P=0.1	10	10	.87
From P=0.5 to P=0.1	15	10	.95
From P=0.2 to P=0.1	10	3	.10
From P=0.2 to P=0.1	15	3	.15
From P=0.2 to P=0.1	10	4	.16
From P=0.2 to P=0.1	15	4	.19
From P=0.2 to P=0.1	10	5	.22
From P=0.2 to P=0.1	15	5	.24
From P=0.2 to P=0.1	10	10	.30
From P=0.2 to P=0.1	15	10	.35

Even under this best case scenario it can be seen that it will be very unlikely to see small changes in probabilities (from 0.2 to 0.1). On the other hand large scale trends (from 0.5 to 0.1) can be detected from 5 to ten years under these assumptions, but this is likely to require a longer period as this is a best case scenario. We propose to utilize the pilot program to answer the question of "How long, given the measured variability in the pilot study, will it take to detect trends?"

The proposed pilot program would be an abbreviated version of the Harbor Monitoring Program Design. The proposed pilot would consist of two strata types - Freshwater input and marina strata, with 10 samples from each stratum. Analytes would be limited to a subset of those that have been shown to be high in harbors: sediment metals (copper, zinc, lead), water quality metals (total and dissolved copper, lead, zinc), TOC, grain size, water quality physical parameters, sediment toxicity of *Eohaustorius*, and benthic community assessment. The pilot program would monitor for three years to gather data. If the pilot program is conducted in 2005, 2006, and 2007, the full program could be conducted at the same time as the Bight 2008 program.

References

Cohen, J. 1977. Statistical Power Analysis for the Behavioral Sciences, Revised Edition. Academic Press, New York. 474 p.

Commission of Southern California Coastal Water Research Project. Bight '98 Steering Committee. 1998. Southern California Bight 1998 Regional Marine Monitoring Survey (Bight '98) Coastal Ecology Workplan. 67 p.